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Using ΔE Distribution as a predictor of digital proofing performance

Raul Eduardo Gonzalez Dorbecker

Using ΔE Distribution as a Predictor
of Digital Proofing Performance

by

Raul Eduardo Gonzalez Dorbecker

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Thesis Advisor: Professor Robert Y. Chung

School of Printing Management and Sciences
Rochester Institute of Technology
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Certificate of Approval

Master's Thesis

This is to certify that the Master's Thesis of

Raul Eduardo Gonzalez Dorbecker

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for the thesis requirement for the Master of Science degree
at the convocation of

September 2000

Thesis Committee:

Robert Y. Chung

Robert Y. Chung
Thesis Advisor

Leonard W. Leger

Leonard Leger
Graduate Program Coordinator

Frank Romano

Director or Designate

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Gonzalez D.

Signature of Author

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Table of Contents

List of Appendices

List of Tables

List of Figures

List of Figures

(continuation)

Abstract

The performance of color matching in ICC-based Color Management Systems (CMS) is being improved, and its workflow established. As part of the digital workflow, digital proofing plays an important roll in the control of color from capture to the printed page, but its method of evaluation is not clearly understood.

To evaluate the degree of color matching by digital proofing in an ICC-based CMS between a reference image and a sample image, the $\overline{\Delta E^*_{ab}}$ calculated by averaging the individual color differences is being used. Doing a qualitative evaluation, ICC-based CMS should be able to stand behind the statement that the color space transformation through the Profile Connection Space (PCS) is correlated to visual judgments. The ΔE^*_{ab} Distribution should provide more information than the average $\overline{\Delta E^*_{ab}}$ to evaluate the degree of color matching in digital proofing.

In this research, the visual judgment between digital proof and a reference image color matches is studied. Using a reference image, and digital proofs as sample images, a psychometric evaluation based on the one-dimensional scaling technique is applied to scale the visual assessments. From the three dimensions: lightness, chroma, and hue; the lightness (L*) dimension was the only aspect addressed to scale the visual assessments.

The reference image was generated with the color characterization data for Type 1 printing [1], and digital proofs with the input data characterization of 4-color process printing (IT8.7/3 target) [2,3]. Those digital proofs were presented to a panel of observers; data were collected, and analyzed to develop a preference scale that represents the qualitative evaluation of the color match.

To test the accuracy of the ΔE^{*}_{ab} Distribution for evaluating the degree of color matching, a quantitative analysis was done. The ΔE^{*}_{ab} Distribution was analyzed by the cumulative frequency distribution technique between the reference image and the digital proofs, for 182 patches of the IT8.7/3 target, and the best critical value to match the visual scale was obtained. A quantitative evaluation between the digital proofs and the reference image, based on the color characterization data for Type 1 printing [1,4], was used to scale the average $\overline{\Delta E^{*}_{ab}}$ and the ΔE^{*}_{ab} Distribution. Then, a classical statistical method was applied to those metric scales and to the visual scale to infer that the degree of color matching is better correlated between the visual judgement and the ΔE^{*}_{ab} Distribution, than between the visual judgement and the average $\overline{\Delta E^{*}_{ab}}$.

Finally, using this method based on the qualitative analysis, a median of the ΔE^{*}_{ab} Distribution of 52.8% would produce a visual match between the reference and the sample.

Endnotes for Abstract

1. ANSI CGATS TR 001-1995 Graphic technology – Color characterization data for Type 1 printing.

2. ISO 12642:1997 Graphic technology – Prepress digital data exchange – Input data for characterization of 4-colour process printing.

3. ANSI IT8.7/3. Graphic technology – Input data for characterization of 4-color process printing. Reston, Virginia. June 21 (1993).

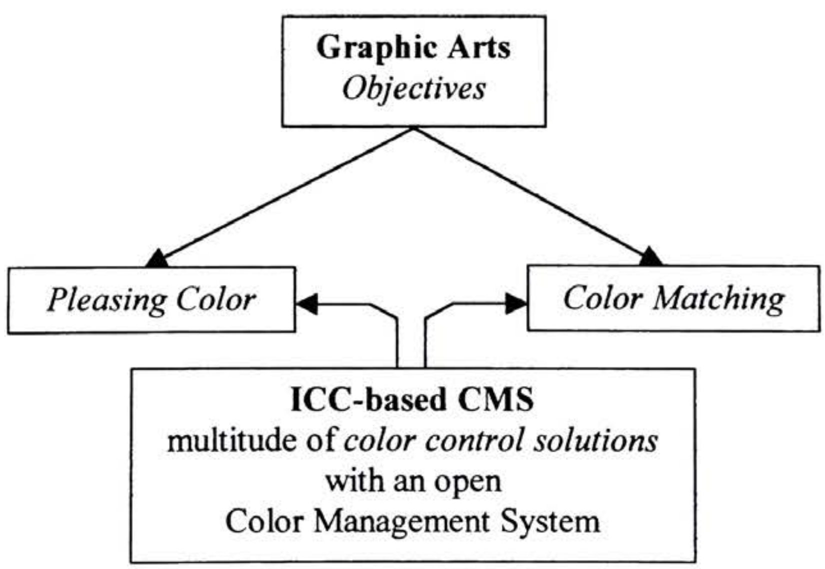
4. ANSI CGATS.6-1995 Graphic technology – Specifications for graphic arts printing - Type 1.

Chapter 1

Introduction and Statement of the Problem

In the Graphic Arts, the most important goals [1] are color matching and pleasing color images, as shown in Figure No. 1. With the formation, in 1993, of the International Color Consortium (ICC), the development of the color management system (CMS) has been promoted to provide color control solutions to Graphic Arts imaging requirements. With the specification of the ICC-Profile Format [2], ICC is working on an open color management system concept, with a multitude of solutions. Vendors want a unique product. Users want a unique solution. The workflow is clear but testing of workflows is still unclear.

Figure No. 1. ICC-based CMS color control solutions for the Graphic Arts industry

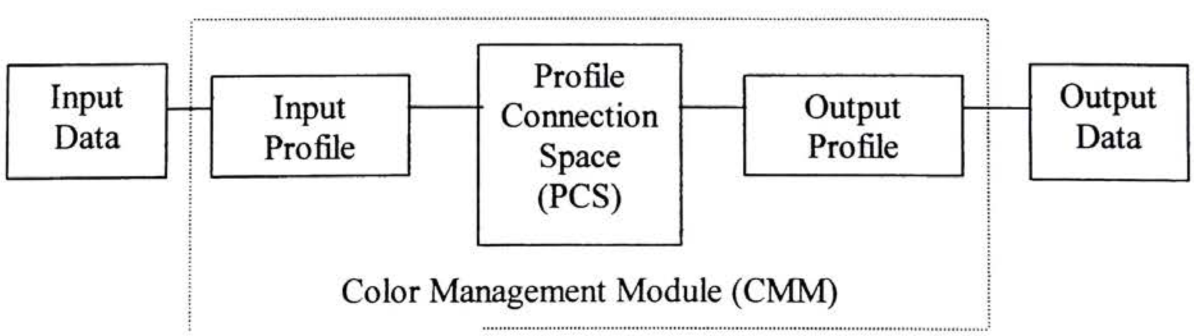


In the case of digital proofing, to evaluate the degree of color matching in ICC-based color management between a reference image and a sample image, the $\overline{\Delta E^*_{ab}}$ calculated average of the individual color differences is being used. Then, $\overline{\Delta E^*_{ab}}$ is being used as a matching scale. A brief description of ICC-based color management concepts follows.

The Color Management System (CMS) is a three-component control of the color reproduction process, from scanning to printing (including displaying and proofing). The three components are:

1) The adoption of a Device-Independent color space, known as the Profile Connection Space (PCS);
2) The establishment of a connection between device color space and the Device-Independent color space, known as a device profile; and,
3) The transformation of the image from sources to output through a specific color management module (CMM). A diagram of ICC-based CMS is shown in Figure No. 2.

Figure No. 2. Diagram of ICC-based CMS



A device profile is a file that has all the characteristics of the color reproduction of that device. The most used device profiles are: input profile, monitor profile, and output profile. An Input profile results from characterization of scanners or digital cameras, output profiles from printers or proofers.

One portion of the Device-Independent color is the profile connection space (PCS) that uses either the tristimulus values (XYZ) or a derivation proposed by the Commission International de L'Eclairage (CIE), named CIELAB. The connection between device profiles is a file that all devices can read. It is created after calibration and characterization [4] steps that are done to adjust and describe the device behavior.

The CMM makes the transformation from the color space of one device to that of another. In most of the cases, this transformation is done through one of several methods for interpolation between color space data.

An important part of the color reproduction process is proofing. Proofing is a visual verification. In the process of proofing, a simulation of ink-on-paper printing is done. The proof can be made by two basic methods: analog off-press proof, and digital proof. In spite of ICC supporting 3-color to 4-color management, the current CMS for digital proofing has a preferred workflow: the CMYK-to-CMYK workflow, where the PCS is CIELAB, the printers are calibrated to a known ink-paper-device condition, and the printer profiles can use one of the three different available rendering styles: perceptual, colorimetric (relative and absolute), and saturation style (those styles are discussed in detail in Chapter 2: Theoretical Bases of the Study).

Due to the different ink-paper-device conditions used in the printing process and the characteristics of the transformation from the color space of one device to that of another, proofing styles, the press sheets and proofs may not match.[4] This lack of color control is determined here by evaluating the color matching performance through a quantitative study.

The quantitative study based on the CIE 1976 color difference is a common practice in the Graphic Arts industry because it is easier than the perceptual analysis. The color difference (average $\overline{\Delta E^*_{ab}}$) is evaluated globally as an arithmetic mean in data from the IT8.7/3 target.[5] This global $\overline{\Delta E^*_{ab}}$ evaluation, as has been demonstrated [6,7], assumes a Gaussian distribution when it is done within the printing process.

In the digital proofing workflow, the global $\overline{\Delta E^*_{ab}}$ evaluation has been taken as valid. However, this assumption has to be reconsidered because the sort of distribution resulting between the press sheet and the proof may affect the color matching. In this connotation, Dolezalek [6] has recommended considering a distribution to achieve an accurate determination of color matching.

Therefore, ICC-based CMS color matching may be better understood if the parameter (ΔE^*_{ab}) for color matching is studied from the point of view of a distribution.

The objective of this research is to study the following aspects of a CMS performance:

(1) The assumption of mismatch between the average $\overline{\Delta E^{*}_{ab}}$ scaling and the perceptual scaling, and

(2) The degree of color matching in digital proofing using ICC-based CMS through the ΔE^{*}_{ab} Distribution process instead of the average $\overline{\Delta E^{*}_{ab}}$.

The focus off this study is the use of ΔE^{*}_{ab} Distribution in digital proofing to determine how effective color matching is in the CMYK-to-CMYK workflow. The assumption of another distribution, different from Gaussian, of IT8.7/3-based color differences between the reference and the digital proof may help in the study of color mismatching.

Endnotes for Chapter 1

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Chapter 2

Theoretical Bases of the Study

The theoretical basis for this study has been divided into three parts: the color difference formulae ΔE^*_{ab} proposed by the CIE, the ICC-based CMS, and the Psychometric technique.

In the study of the color difference formula, the CIELAB color space, the lightness, chroma and hue correlation, and the ΔE^*_{ab} distribution topics are required concepts. Those concepts are developed in this chapter before discussing the ICC-based CMS case, with its CMM and PCS concepts. Finally the issues of the Psychometric technique are discussed.

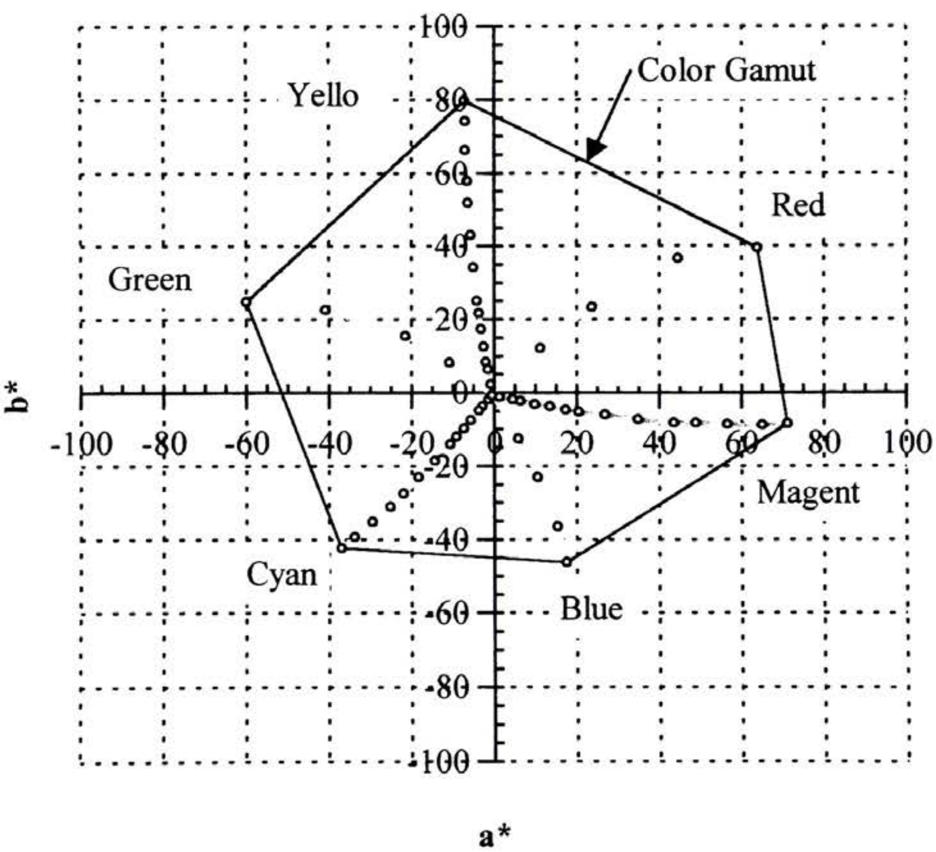
CIELAB color space

An ICC-based CMS is based on mathematic models derived from CIELAB, a brief introduction to CIELAB color space and its derived ΔE^*_{ab} color difference equation follows.

The CIELAB color space involves nonlinear functions of the tristimulus values (X, Y, Z), and the reference substrate (X_n, Y_n, Z_n) that usually correspond to those of the standard illuminant with Y_n equal to 100.[1]

However, CIELAB is easy to interpret when a*/b* diagrams are used to view a color gamut. In this diagram, a* is a representation of the redness-greenness, and b* is a representation of the yellowness-blueness of the color, as shown in Figure No. 3. The "circle" (continuous line) represents the maximum color gamut and the lines, coming from the center (neutral color area) that meet the color gamut line, are the color lines representing the tone scales for cyan (C), magenta (M), yellow (Y), red (R), green (G), and blue (B).

Figure No. 3. Color gamut in the a*-b* diagram



The mathematics involved in this color space can be expressed as follows.

$$L^* = 116\Psi\left(\frac{Y}{Y_n}\right) - 16$$

$$a^* = 500\left[\Psi\left(\frac{X}{X_n}\right) - \Psi\left(\frac{Y}{Y_n}\right)\right]$$

$$b^* = 200\left[\Psi\left(\frac{Y}{Y_n}\right) - \Psi\left(\frac{Z}{Z_n}\right)\right]$$

where

$$\Psi\left(\frac{X}{X_n}\right) = \begin{cases} \left(\frac{X}{X_n}\right)^{1/3} & if \quad \frac{X}{X_n} \rangle \ 0.008856 \\ \left[7.7867\left(\frac{X}{X_n}\right) + \frac{16}{116}\right] & if \quad \frac{X}{X_n} \leq 0.008856 \end{cases}$$

and equivalent equations for the ratios (Y/Y_n) and (Z/Z_n). The term L* is the CIE 1976 *lightness*.

For these calculations, the values for D50, 2° observer, and the white point with [2]

$X_n =$ 96.422

$Y_n =$ 100.000

$Z_n =$ 82.521

shall be used, as stated in the ANSI CGATS.5.[2]

Color difference ΔE^*_{ab}

The color difference ΔE^*_{ab} is a comparison between a single color and its reference. The mathematics of this color difference in terms of the CIELAB is called CIE 1976. The color difference formula follows:

$$\Delta E^*_{ab} = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2}$$

Where the particular differences are:

in lightness	$\Delta L* = L*_{sample} - L*_{reference}$,
in a* coordinate	$\Delta a* = a*_{sample} - a*_{reference}$,
in b* coordinate	$\Delta b* = b*_{sample} - b*_{reference}$

The interpretation of the color difference ΔE^*_{ab} is the difference between the spatial position of a color (sample) and the spatial position of the other color (reference). Based on Chung's [4] and Beckmann and collaborators' [5] work, the ΔE^*_{ab} yardstick may be stated as shown in Table No. 1. At this point, it must be recognized that inaccuracy of measurement can contribute a ΔE^*_{ab} equal to 1.2 unit +/- 0.5 units.[6]

Table No. 1. ΔE^{*}_{ab} Yardstick.

ΔE^{*}_{ab} **units**	**Match** [4]	**Evaluation** [5]
< 0.2	Excellent	Invisible
0.2 to 1.0		Very low
1.0 to 2.0	Good	Low
3.0 to 4.0		Medium
4.0 to 6.0	Fair	
> 6.0	Poor to no longer Considered as a match	High

Lightness, Chroma, and Hue correlation

To identify those terms in the CIELAB color difference equation, the following quantities are defined [3]:

$$C^{*}_{ab} = \sqrt{(a^{*})^2 + (b^{*})^2}$$

$$h_{ab} = \tan^{-1}\left(\frac{b^{*}}{a^{*}}\right)$$

where

h_{ab} is the CIE 1976 a,b *hue-angle*, and

C^{*}_{ab} is the CIE a,b *chroma.*

This defines hue angles to specify hue numerically, with the following conventions:

$$0° \le h_{ab} < 90°, \quad \text{if} \quad a^* > 0, \; b^* \ge 0$$

$$90° \le h_{ab} < 180°, \quad \text{if} \quad a^* \le 0, \; b^* > 0$$

$$180° \le h_{ab} < 270°, \quad \text{if} \quad a^* < 0, \; b^* \le 0$$

$$270° \le h_{ab} < 360°, \quad \text{if} \quad a^* \ge 0, \; b^* < 0$$

Color difference ΔE^*_{94}

The CIE 1994 colour-difference, ΔE^*_{94}, introduces the parametric factors and weighting functions [7] and the derivation of the Hue difference to improve the color difference ΔE^*_{ab} equation in some applications.

Using the Hue difference as:

$$\Delta H^*_{94} = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 - (\Delta C^*)^2}$$

the improved color difference equation is [8]:

$$\Delta E^*_{94} = \sqrt{\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^*_{ab}}{k_H S_H}\right)^2}$$

where the weighting functions:

$S_L = 1$

$S_C = 1 + 0.045\ C^*_{ab}$

$S_H = 1 + 0.015\ C^*_{ab}$

when any of the two members of the color difference pair can be selected as the reference, CIE recommends [8] using the mean chroma for calculation of the weighting functions S_C and S_H. When the mean is taken as the reference chroma, CIE recommends [8] using the geometric mean chroma as:

$$C^*_{ab} = \sqrt{C^*_{ab,reference} \times C^*_{ab,sample}}$$

On the other hand, the parametric factors:

$k_L = 1$

$k_C = 1$

$k_H = 1$

have been stated for the reference conditions [8]:

Illumination:	D65 simulation
Illuminance:	1,000 lux
Viewing mode:	object
Sample color-difference magnitude:	0-5 CIELAB units
Surround field:	uniform, neutral gray with L*=50

Based on research conducted by Robertson, a better choice for k_C would be 2 units.[9]

ΔE^*_{ab} and ΔE^*_{ab} Distribution

Evaluating ΔE^*_{ab} between two colors, color reference and color sample, is the meaning of CIELAB color difference for those two specific colors. Evaluating ΔE^*_{ab} between image elements has two characteristics: central tendency, and range. The central tendency includes the average ΔE^*_{ab}, the median, and the mode. The range is given by $\Delta E^*_{ab,\max}$ and $\Delta E^*_{ab,\min}$ values. An average of all the color differences, evaluated over all the colors in a color target, may introduce an incorrectly weighted color variation when doing color matching between a reference and a digital proof.

It is a practice in the ICC-based CMS process to evaluate the average color difference that assumes the color differences for individual colors have a Gaussian distribution. When ΔE^*_{ab} distribution is Gaussian, the average ΔE^*_{ab} will be equal to the ΔE^*_{ab} median, and equal to ΔE^*_{ab} mode. The Gaussian distribution implies that a test target with more patches will generate a high degree of color matching as it is interpreted by statistic theory.[10] Instead of an increase in accuracy with an increase in the quantity of patches, what is observed [11,12,13] is a lower degree of color matching.

The theory is that CIELAB uses coordinates (L*, a*, and b*) to establish the position of a color in the Euclidean space, and these coordinates are distributed with Gaussian statistics because they vary around the mean value, in the positive and the negative directions.

The evaluation of ΔE^*_{ab} is done by the sum of the squared differences between the variables L*, a*, and b*. These square differences imply that ΔE^*_{ab} will hold only positive values, although these positive values may follow an asymmetrical distribution.[11,12]

ICC-based CMS

As mentioned before, eight industry companies founded the International Color Consortium (ICC) in 1993,[14] for the purpose of:

"...creating, promoting and encouraging the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture and components."

Their goals were formally established later, in Palo Alto, California, in 1996 (Stokes, 1997) [14]:

"1. The color management system should scale from automatic to sophisticated user intervened conditions.

2. The ICC will incorporate new technology and standards in a timely manner. ICC work will be offered to the relevant standards body for consideration as an International Standard.

3. To create, promote, and encourage the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture and components.

4. The ICC will define a baseline CMM [color management module] model and baseline CMM implementation that can be part of the specification that will provide the same results with the same numerical data.

5. The ICC will standardize on an appearance model(s) to get from source to PCS and PCS to destination.

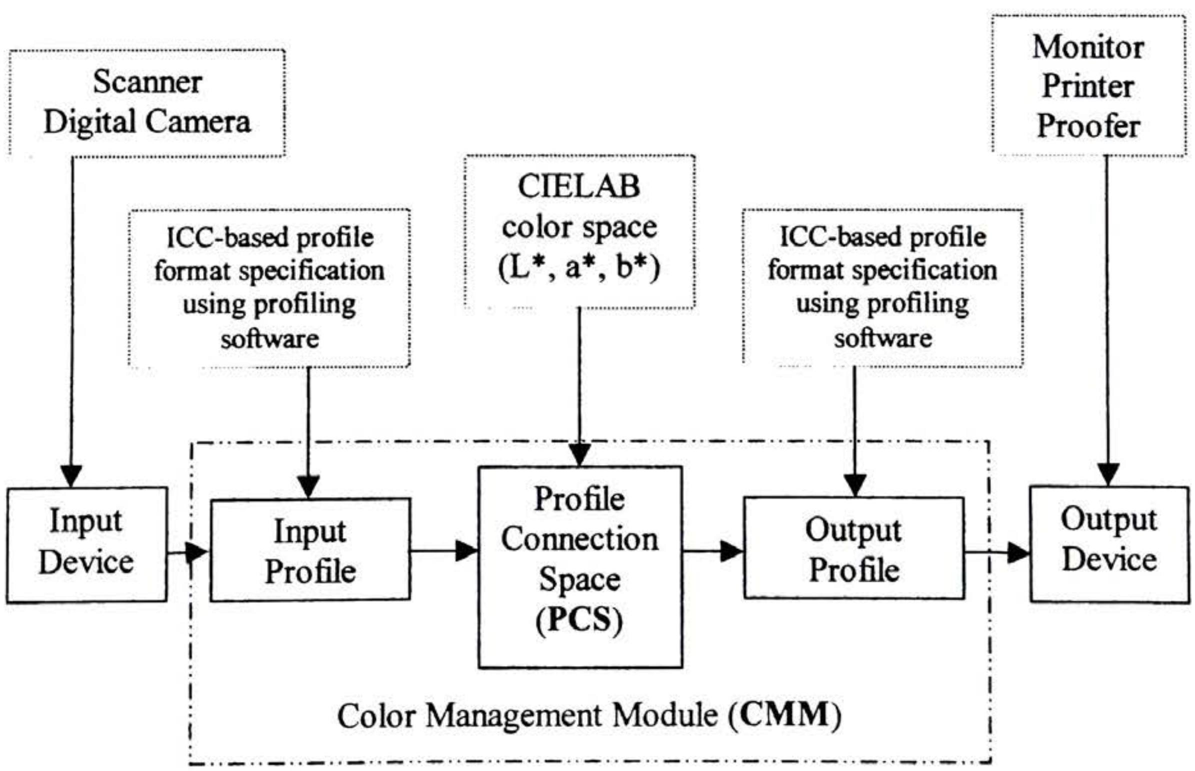
6. Colorimetric reproductions (absolute and relative) should be exact within the tolerance of the device within the device's gamut."

The development of color management has been promoted to provide color control solutions to graphic arts imaging requirements. The CMS is a three-component control of the color reproduction process. The three components are:

1) The adoption of a Device-Independent color space
2) The establishment of a connection between device color space and the Device-Independent color space
3) The transformation of the image from sources to output through a specific color management module (CMM).

A diagram of ICC-based CMS, with the CMM and the PCS, is shown in Figure No. 4.

Figure No. 4. Elements of ICC-based CMS



A device profile is a file that has all the characteristics of the color reproduction of that device. The most used device profiles are: input profile, monitor profile, and output profile. Input profiles result from characterization of scanners or digital cameras; output profiles from printers or proofers.

One portion of the Device-Independent color is the profile connection space (PCS) that uses the tristimulus values (XYZ) or a derivation proposed by the Commission International de L'Eclairage (CIE), named CIELAB. PCS has been defined [15,16] as:

> "...the CIE Colorimetry which will produce the desired color appearance if rendered on a reference imaging media and viewed in a reference viewing environment."

The connection between device profiles is created after calibration and characterization [17] steps (which are done to adjust and describe the device behavior) are completed. Calibration is done to adjust a device to known values. Characterization results from measurement of a device output from a known input.

The CMM makes the transformation from the color space of one device to that of another. In most of the cases, this transformation is done through one of several methods for interpolation between color space data.

In spite of ICC supporting 3-color to 4-color management, the current CMS for digital proofing has a preferred workflow: the CMYK-to-CMYK workflow. Printers are calibrated to a known ink-paper-device condition, and the printer profiles can use one of the three different available rendering styles: perceptual, colorimetric (relative and absolute), and saturation style.

The perceptual rendering style (or intent) optimizes the image (appearance) quality, maintaining the color-to-color relationship, as the colors are mapped to the printer gamut, in spite of the fact that the color values can change. In other words [15,16]:

> "...specifies the full gamut of the image is compressed or expanded to fill the gamut of the destination device....colorimetric accuracy might not be preserved."

The colorimetric rendering style optimizes the accuracy of colors, and can be realized relative to the white point of the media, or absolute (white point of the standard).

In the relative colorimetric case, the out-of-gamut colors are transformed to color that have the same lightness but fall just inside the gamut. In the absolute colorimetric case, the white point matching is disabled when converting the colors.

The saturation rendering style maintains the saturation of colors. Thereby, the out-of-gamut colors are transformed to colors that fall just inside the gamut with the same saturation. Hue and lightness may lack accuracy.

Psychometric experiment

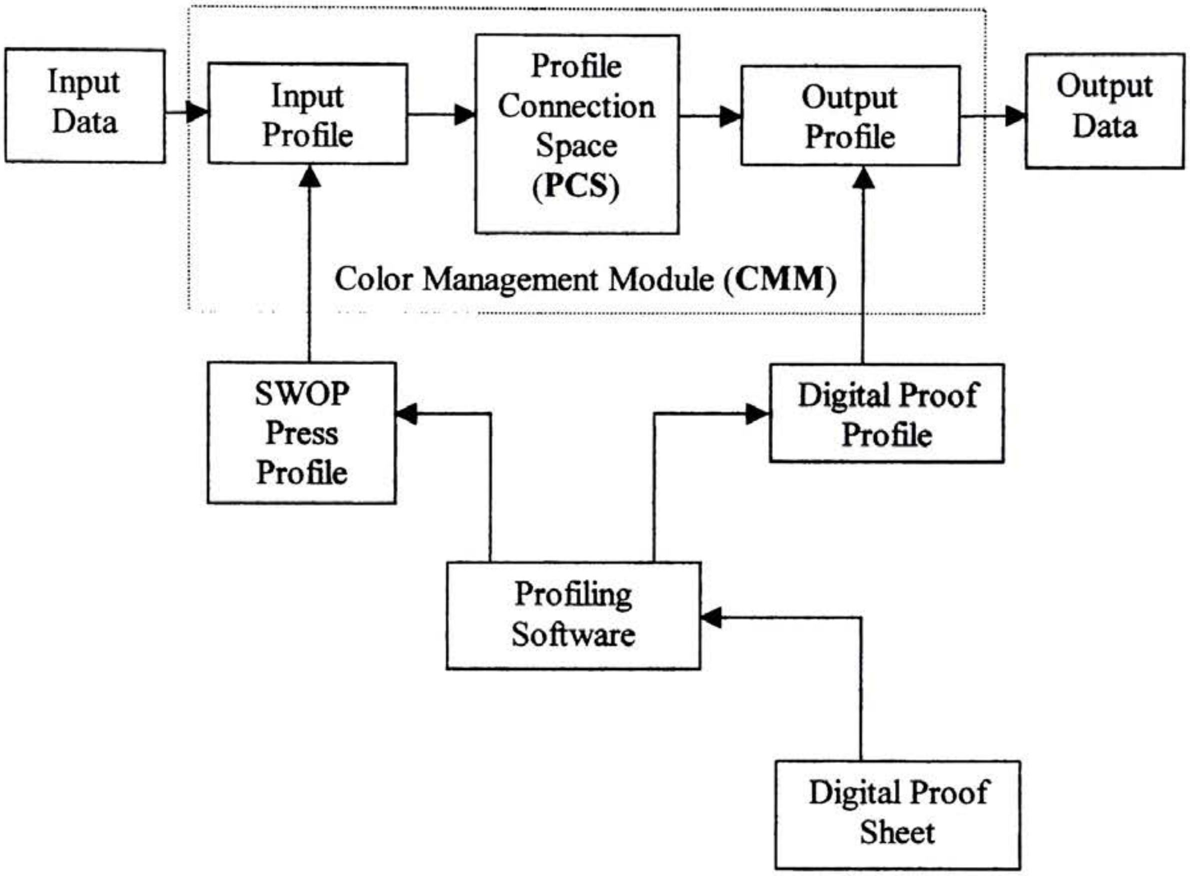
To create a visual scale, a scaling method called Partition Judgments was used. This technique is only one of eight scaling methods [18,19] that integrate the general unidimensional scaling experimentation. In this research, a five-step process was applied to use the Partition Judgments technique:

1. Preparation of the test images
2. Selection of the panel
3. Presentation of the images to the panel
4. Data collection
5. Data analysis

To prepare the test images, a digital proof profile was made using a profiling software (described in Chapter 5: Methodology), the Color characterization data for Type 1 printing [12] and the digital proof, as shown in the Figure No. 5.

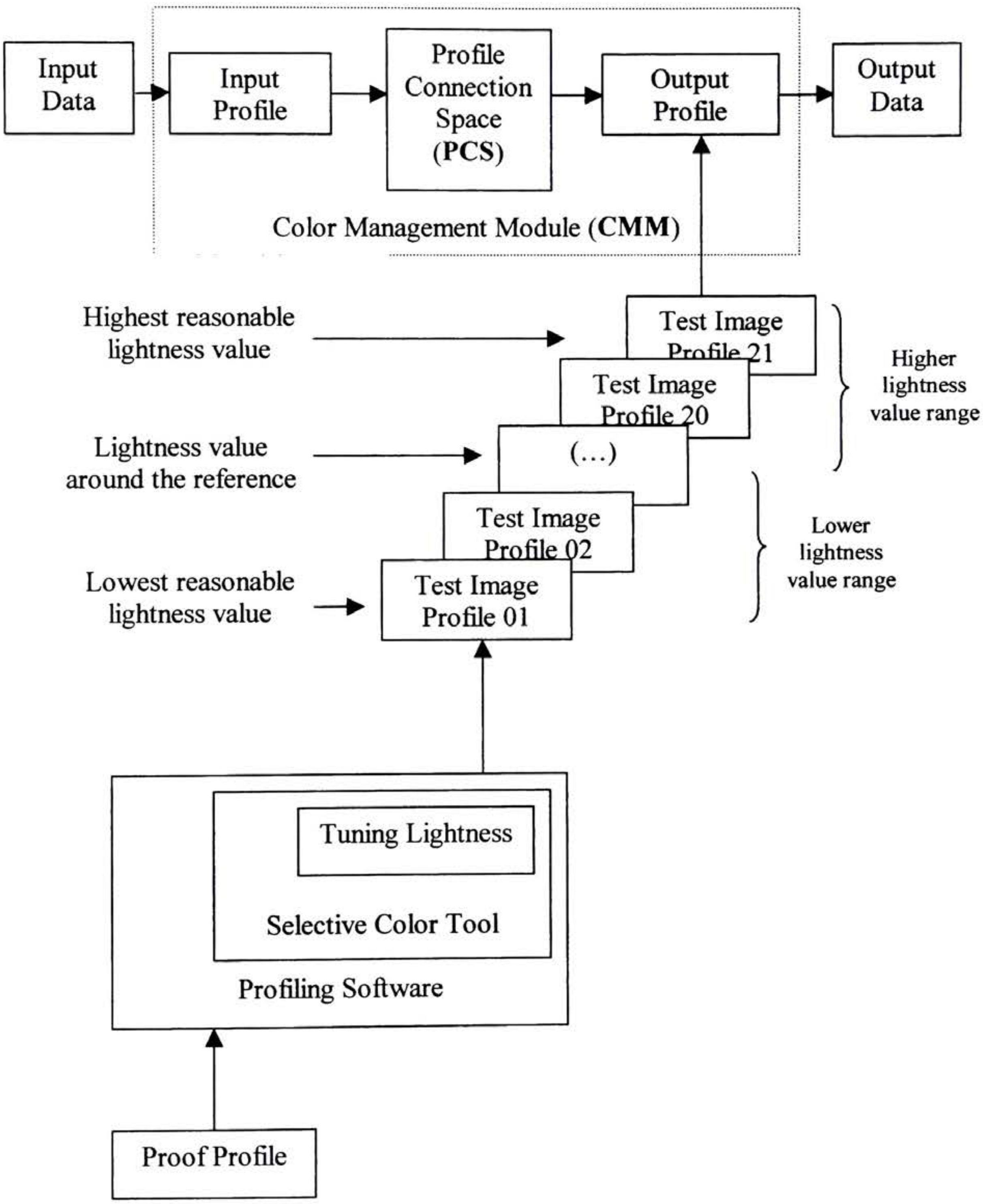
After the generation of the digital proof profile, the production of several test image profiles is required. These test images profiles *were differentiated by different lightness values around the lightness value of the digital proof profile*, with the same five-unit distance on both sides of the lightness scale of the profiling software. The psychometric experiment was conducted in two parts: one with lower lightness value range (from 0 to 50 units) and the other with higher lightness value range (from 50 to 100 units).

Figure No. 5. Reference profile and output device profile generation using a profiling software and the SWOP press profile



Tuning lightness from the selective color tool in the profiling software generates the perceptual difference between test image profiles, as shown in Figure No. 6. The test image profiles were used to print the test images for the psychometric test, for both ranges mentioned before, lower and higher lightness value ranges.

Figure No. 6. Generation of the test image profiles by tuning lightness from the selective color tool in the profiling software

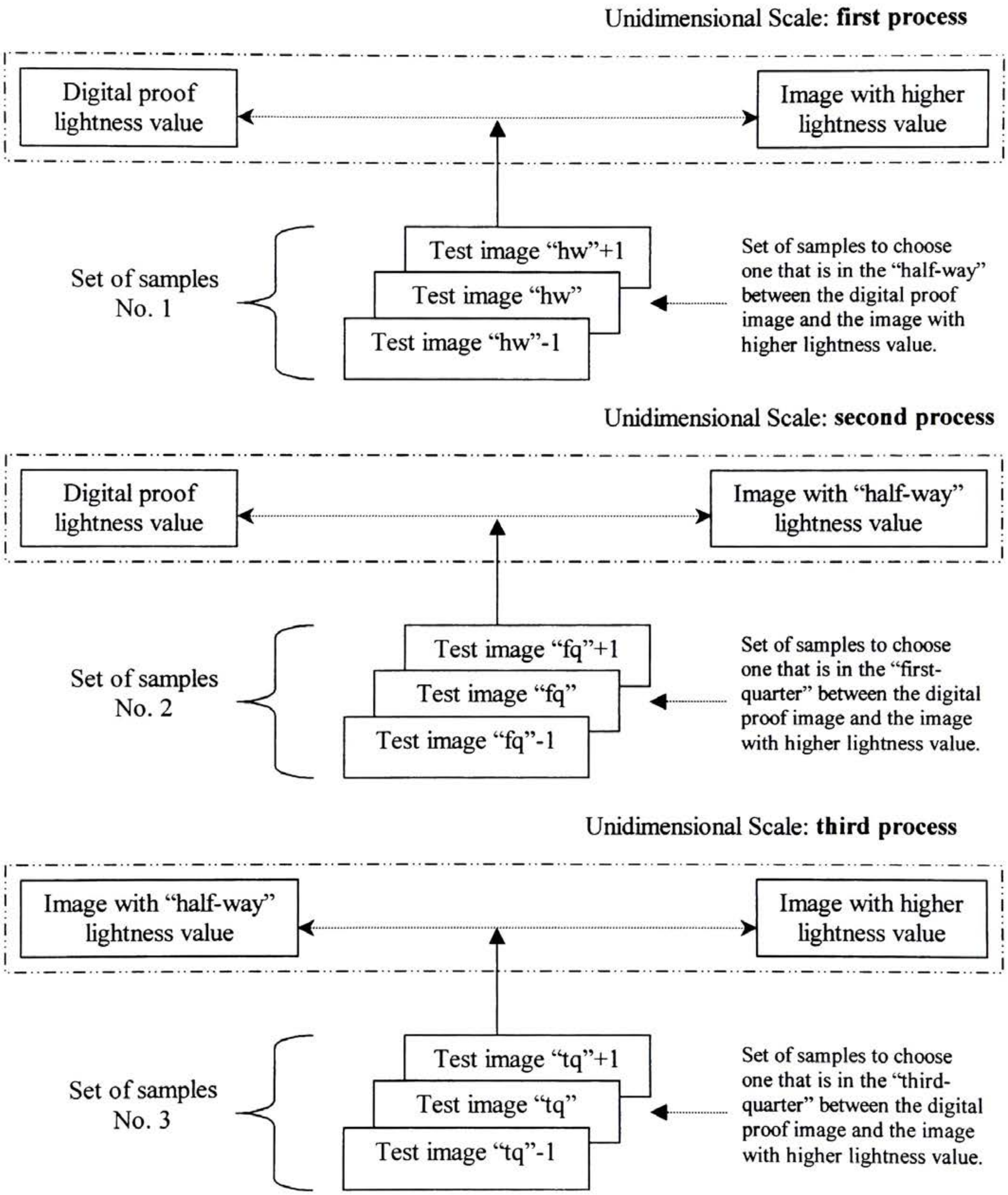


To select the panel, the Farnsworth-Munsell 100 Hue (FM 100 H) Test was applied to a group of volunteers. The FM 100 H test is a test for normal color vision based on the observer's order decision over a set of patches covering different hues. This test is recommended for the analysis of color defectives. Sometimes referred to as a test for normal color vision because the abnormal color vision can be indicated by a wrong order of the test chips. Once the group of volunteers was tested, a panel of observers was selected from those volunteers who past the test.

The presentation of the images to each observer was performed after a brief set of written instructions (see Appendix E), making sure the instructions were understood. The images were presented to the panel of observers in a sequence of sets of samples described in Figure No. 7 for both lightness value ranges, where:

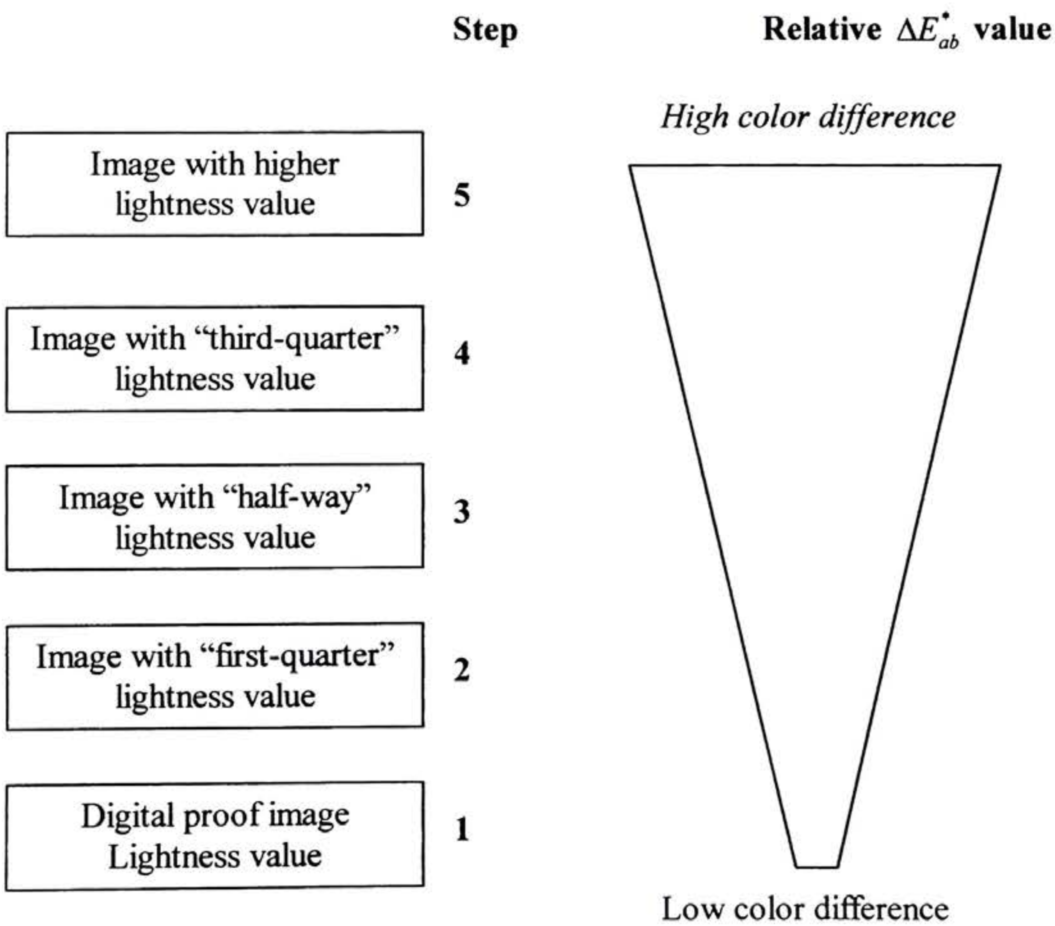
- The set No. 1 was composed of images with uniform variations in lightness around the medium lightness value between the digital proof (that match the color of the reference) and the highest reasonable lightness value. From this set, each observer selected a "half-way" lightness value.
- The set No. 2 was selected from images with uniform variations in lightness between the lightness of the digital proof and the "half-way" lightness value. From this set, each observer selected a "first-quarter" lightness value.
- The set No. 3 was selected from images with uniform variations in lightness between the lightness of the "half-way" lightness value and the highest reasonable lightness value. From this set, each observer selected a "third-quarter" lightness value.

Figure No. 7. Unidimensional Sampling processes to obtain a visual scale



Finally, from the panel of observers' judgments, a five step visual scale was developed for the entire lightness value range, with equal intervals between them. In Figure No. 8, the five-step visual scale and the relative ΔE^*_{ab} value are shown for the higher lightness value range. For lower lightness value range the geometric figure would be in the opposite direction

Figure No. 8. Five-step visual scale and the relative ΔE^*_{ab} value



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Chapter 3

Review of the Literature

Since the first color matching tests (Chung and Kuo [1]), digital proofing through ICC-based CMS has been improving, but it is still yielding mismatched colors as Chung and Komori [2] predicted: "Color matching using ICC-based CMS is no better than a calibrated film-based proofing system."

Color mismatching in digital proofing can be sorted into three groups: mismatching due to the device, mismatching due to the software, and mismatching due to the evaluation method.

In the first group, Wei, Shyu, and Sun [3] affirm that the most important cause of mismatching is related to the device characterization. They have shown that the device introduces color variation because of its limits of color reproduction, i.e., its color gamut. Griffon, et al [4] studied the magnitude of these variations in color, introduced by the device. They found that these device variations follow a symmetric distribution (similar to Gaussian), when the device is a scanner; but that for a printer appears asymmetric as may be the case for digital proofing. This means that color mismatching is strongly dependent on the type of device. Chung and Komori [2] determined that device calibration and its relationship to the control of the printing process, is the source of the color error introduced.

In the second group, researchers have found that the color variations have an important dependency on the software. Wei and his collaborators [3] had found that the color space (PCS) used is one of the origins for variations. Griffon, et al [4] suggest that the data processing done by the software is the cause. In their work, Chung and Komori [2] found that the variation also depends on the characteristics of the profiling software.

In the last group, some researchers show that the color mismatching may be due to the evaluation method. Dolezalek [5] has performed the most important work in this area. The Dolezalek work relates the variation involved in the method itself and the test target used. He states that the variations are related to the calculation method because they follow an asymmetrical distribution in the ΔE^*_{ab} evaluation. This is opposite to the practiced Gaussian distribution in CMS that can be related to the digital proofing performance.

A group of researchers that has studied the ΔE^*_{ab} Distribution (Dolezalek and Griffon, et al) concluded that there are more things to study in order to understand the digital proofing performance and the management of the color difference evaluation. In this direction, some authors have dedicated their work to understand the performance by studying the mismatch between visual assessment and the CIE average $\overline{\Delta E^*_{ab}}$; Pointer and Attridge,[6,7] Witt,[8] and Guan and Luo [9] all agree that color matching has not been deeply tested.

Pointer and Attridge have found that the correlation between visual assessment and $\overline{\Delta E^{*}_{ab}}$ is a very difficult task. This is a very subject-and-observer-dependent matching.[10] They have found great differences between the evaluation using different equations to evaluate the color-differences. In addition, they suggest using other color-difference equations. Witt states the color difference mismatch between the visual assessment and the metric depends on the magnitude of the color difference. So, for small color differences the color match between scales (visual and colorimetric) is better than for large differences. Pointer and Attridge [7] state that "large" color differences using CIELAB space can be greater than 4 units. Guan and Luo have determined that those differences could be over 10 CIELAB units.

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Chapter 4

The Hypotheses

The objective of this research is to study the following aspects of a CMS performance:

a) The assumption of mismatch between the visual scale and the colorimetric scale, and

b) The degree of color matching in digital proofing using ICC-based CMS through the ΔE^*_{ab} Distribution process instead of the average $\overline{\Delta E^*_{ab}}$.

In order to reach this objective, in this chapter are founded the hypotheses, the further analysis, and the limitation of the research.

The hypotheses

Based on the need to verify the mismatching between the visual scale and the colorimetric scale in digital proofing, and because of the unidimensional analysis conduced in this research for higher and lower lightness value ranges, two main hypotheses have been stated as follows and shown in Figure No. 9:

The first hypothesis:

Null hypothesis, $H0_1$

"There is no relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 0 and 50 units."

Alternative hypothesis, $H1_1$

"There is a relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 0 and 50 units."

The second hypothesis is:

Null hypothesis, $H0_2$

"There is no relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 50 and 100 units."

Alternative hypothesis, $H1_2$

"There is a relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 50 and 100 units."

The hypotheses are tested by a non-parametric analysis between the visual scale and the colorimetric scale. From this statistical analysis, the color mismatch is verified when the null hypothesis fails to be rejected. Otherwise, there is a relationship between the scales and the null hypothesis will be rejected.

ΔE^*_{ab} Distribution analysis

ICC-based CMS color matching may be better understood if the parameter (ΔE^*_{ab}) for color matching is studied from the point of view of a distribution, as it has been stated in the introduction.

The further analysis is based on the study of the cumulative frequency distributions of the color differences between the digital proof and its unidimensional variation samples. The cumulative frequency distributions of the color differences are based on the individual color differences for each of the 182 color patches of the IT8.7/3 target. The unidimensional variation is the uniform variation on the lightness scale available on the Profiling Software Color Tools, and is done every five lightness units.

The further analysis will allow a major insight on the degree of color matching in digital proofing using ICC-based CMS through the ΔE^*_{ab} Distribution process instead of the $\overline{\Delta E^*_{ab}}$. The ΔE^*_{ab} Distribution process will provide a graph with a family of curves with different cumulative frequency distributions versus the color differences that will determine a ΔE^*_{ab} Distribution scale, based on a critic threshold.

Then, this analysis will possible to determine whether there is a relationship between the visual scale and the colorimetric scale when using the ΔE^*_{ab} Distribution in ICC-based CMS. The determination has to be done through a non-parametric analysis between the visual scale and the ΔE^*_{ab} Distribution scale. From this statistical analysis, the improved color match of the ICC-based CMS will be tested. If the determination is positive, another important step in the digital proofing technology would have been made.

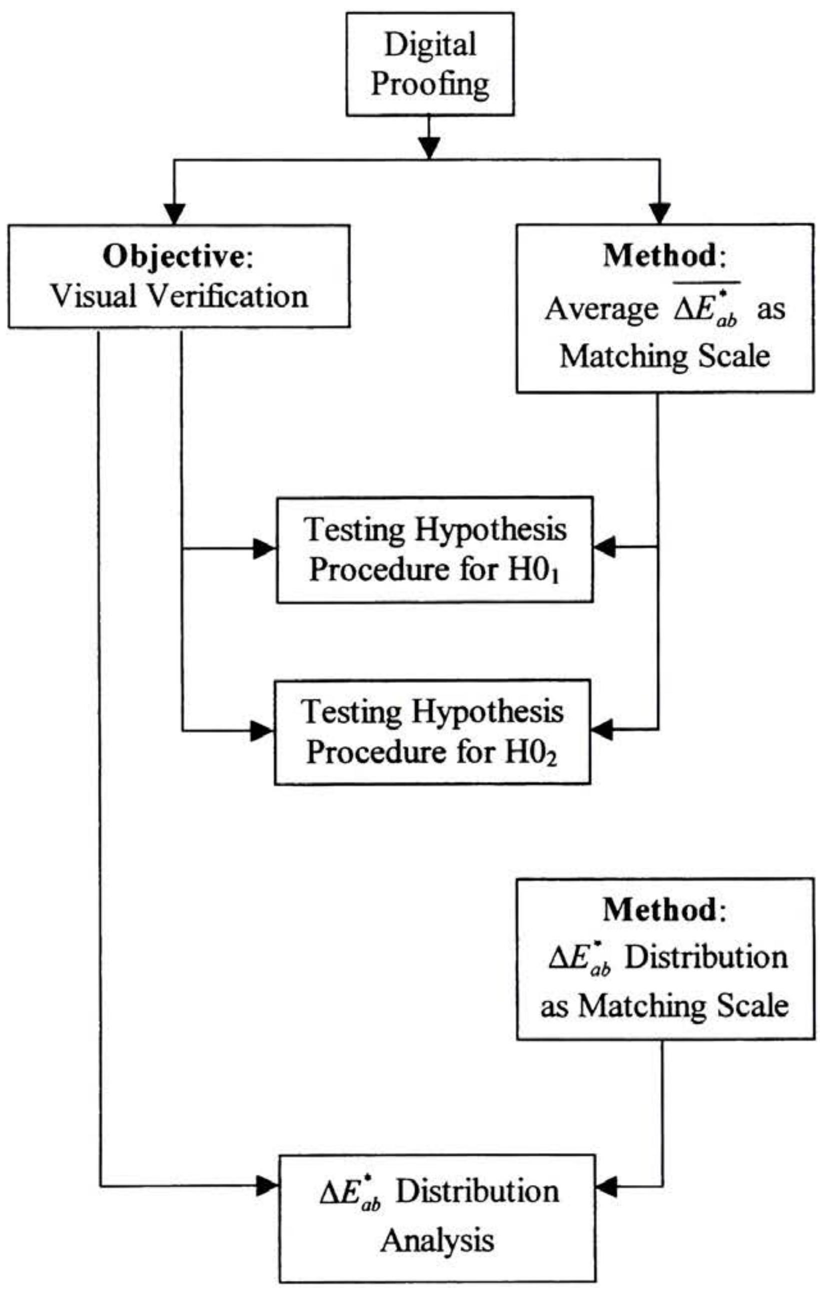
Limitations

This research will be conducted under the following conditions:

1. Lightness scale analyses:	Two separated analysis; from 0 to 50 lightness units, and from 50 to 100 lightness units
2. Operative System:	Mac OS 8.6
3. System based CMS:	ColorSync 2.6
4. Profiling Software:	Kodak Colorflow Profile Editor 2.0
5. Pagination Software:	QuarkXPress™ 4.0

6. Printer Driver:	Epson StylusRIP™ 3.3
7. Measuring Instrument Driver:	GretagMacbeth SpectroServer
8. Measuring Instrument:	GretagMacbeth SpectroLino/SpectroScan
9. Printer:	Epson Stylus Color 3000
10. Test Target:	IT8.7/3 basic data set
11. Paper:	Epson Photo Quality Glossy Paper
12. Toner:	for Epson SC 3000
13. Normal Color Vision Test:	FM-100 Hue test
14. Profiling Target:	Kodak Color*flow* medium-size target

Figure No. 9. Testing Hypotheses in the Digital Proofing environment.



Chapter 5

Methodology

This research verifies the mismatching between the visual scale and the colorimetric scale in digital proofing, and investigates the ΔE^*_{ab} Distribution as a predictor of digital proofing performance. The sources to be used are described as follows, and the method to accomplish this research is described below. It has been separated into eight steps numbered from 0 to 7.

Step 0: Experimental sources

a. Software

   i. Mac OS 8.6
   ii. ColorSync™ 2.6
   iii. Kodak Color*flow*™ Profile Editor 2.0
   iv. QuarkXPress™ 4.0
   v. Epson StylusRIP™
   vi. GretagMacbeth SpectroServer
   vii. Microsoft Excel®

viii. DensiPlot and ColorPlot templates

ix. Adobe® Photoshop® 5.0

b. Hardware

i. Macintosh (G3)

ii. GretagMacbeth SpectroLino/SpectroScan

iii. Epson Stylus™ Color 3000

c. Material

i. Images: Reference pictorial image ISO 12640 SCID S7

ii. Targets:

1. IT8.7/3 basic data set (A1 to N13). Synthetic test target, with CMYK ramps and a total of 182 patches

2. Kodak Color*flow* target (to build profiles)

iii. Paper: Epson Photo Quality Glossy Paper

iv. Inks: Epson SC 3000 ink set

d. Experimental conditions

i. Psychometric test

1. FM-100 hue test for normal color test

2. Viewing Booth D_{50}

ii. Colorimetric analysis (ANSI CGATS.5)

1. Sample backing material (ISO 5/4, Sec 4.7)

2. CIE illuminant (D_{50})

3. CIE 1931 standard colorimetric observer (2° standard observer, CIE 15.2)
4. Measurement geometry 45/0

iii. Profiling

1. Measurement geometry 45/0
2. Measuring diameter 4 mm
3. Light source type A
4. CIELAB
5. 10 nm intervals

iv. Special

1. Imation™ Color Fidelity Module (CFM)
2. Test form for test targets

Step 1: Pre-experimentation

A device consistency test and a material stability test were conducted prior to performing this research. Both tests are pre-experimentation processes required in any formal research.

The device consistency test was conducted by printing four different times using the Epson SC 3000. The printed form contains the test form shown in Appendix A. Epson Photo Quality Glossy Paper was used in all the samples. Every one of the printed samples was measured at the same time after printed, and over the 182 patches of the IT8.7/3 target with the GretagMacbeth SpectroLino/ SpectroScan. The colorimetric data gathered were processed in a Excel template to calculate the average of each patch to be used as reference. The color difference was evaluated between this reference and every sample printed.

The material stability test was conduced printing in the same way as the device consistency test described before. Each printed samples was measured every twenty minutes, and over the 182 patches of the IT8.7/3 target with the GretagMacbeth SpectroLino/ SpectroScan. As in the device consistency test, the colorimetric data gathered were processed in an Excel template.

Step 2: Generation of Reference

Test forms were printed using the Epson SC 3000. The test form included the IT8.7/3 basic target (see Appendix A), and the gray patch related to the 50% of the black ramp of the IT8.7/3 target. Both will be used as the reference. The IT8.7/3 basic target was used to build the colorimetric scale, and the gray patch image was used to build the visual scale. The reference profile was built using the Kodak Color*flow* medium-size target (see Figure No. 10 and Appendices C and F).

Step 3: Generation of Proofs

The IT8.7/3 Target and the gray patch files were printed using the Epson Stylus Color 3000, with different ICC-based CMS conditions described in Chapter 2. A detailed diagram of the generation of proofs is shown in Figure No. 11. The proof profiles were generated as in Step 2: Generation of Reference. In appendix G the Kodak Color*flow* profile generation used is explained.

Figure No. 10. Generation of Reference

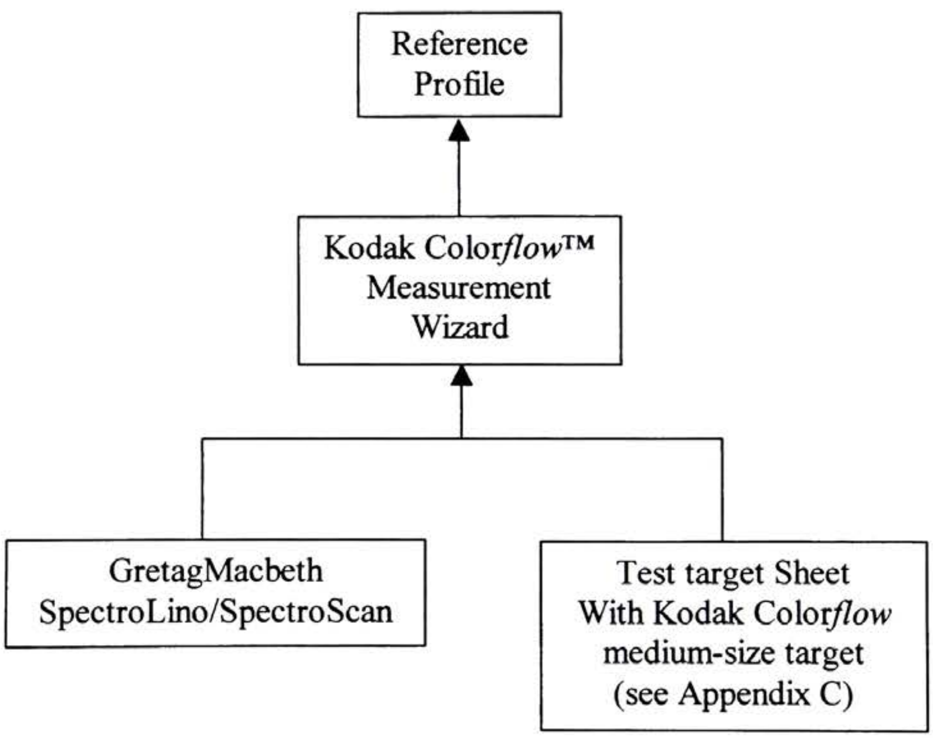
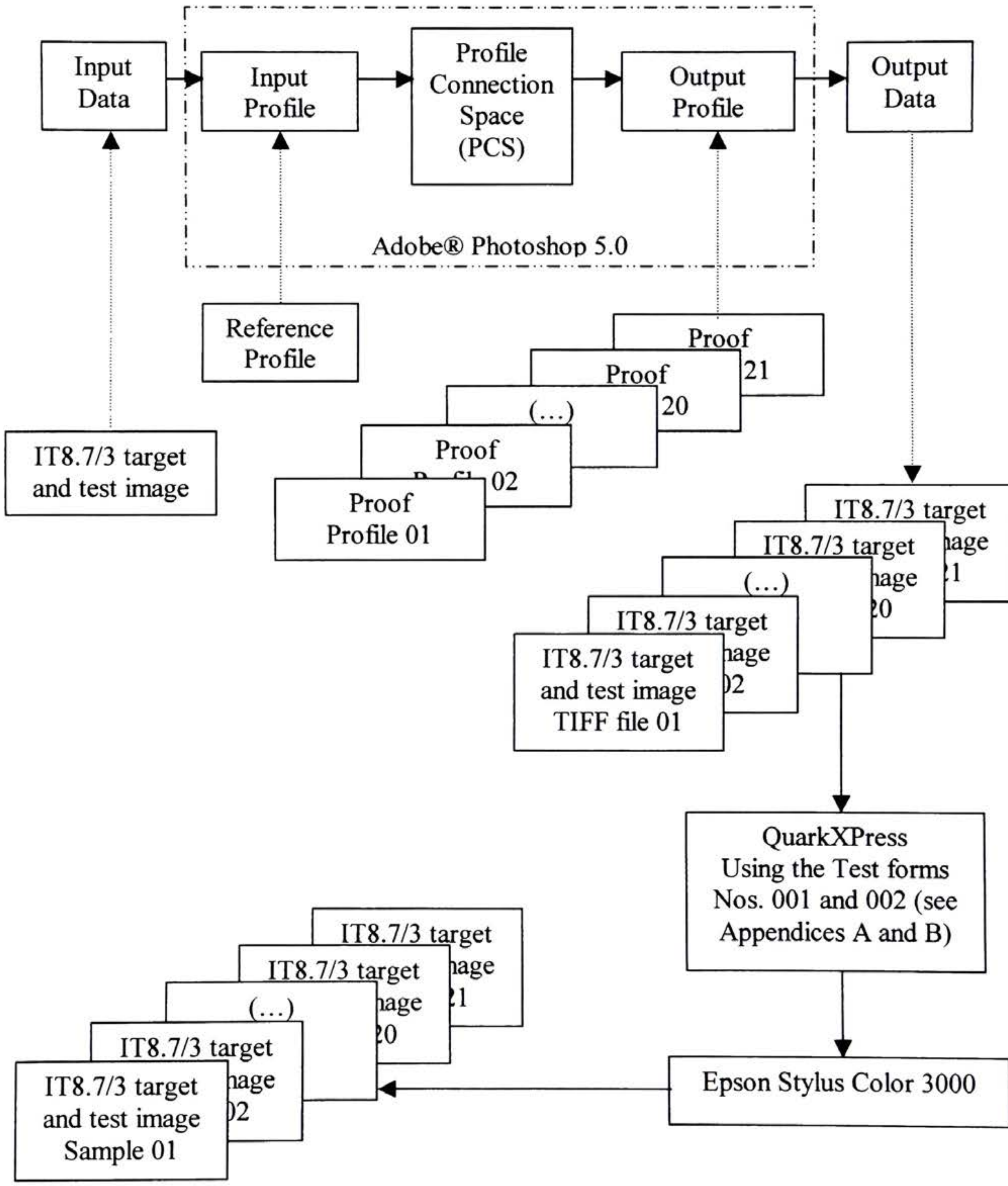


Figure No. 11. Generation of Proofs



Step 4:Psychometric Experiment

The test images described in Chapter 2 were used for the psychometric experiment. The test images were presented to the panel of observers, the data collected, and the analysis made. The presentation to the observers was prepared as follows:

1. A group of volunteers within the Graphic Arts environment were invited.
2. A panel of twenty observers was selected based on the FM 100 Hue test for normal color vision.
3. A brief set of written instructions was presented to each observer (as shown in Appendix E).
4. The Unidimensional Scaling was developed in two parts: one with lower lightness value range (from 0 to 50 units) and the other with higher lightness value range (from 50 to 100 units).
5. The Panel observations were recorded, and the visual scale obtained (see Figures 7 and 8).

Step 5: Colorimetric Evaluation

The samples were measured with the GretagMacbeth SpectroLino/SpectroScan, and the global $\overline{\Delta E^*_{ab}}$ was evaluated. In Appendix "D" the Colorimetric data for all samples are shown in Appendix D.

All the patches (182) contained in the IT8.7/3 target were evaluated in this step. The L*, a*, b* values were recorded in a specific-built template to evaluate ΔE^*_{ab}. The template calculated the ΔE^*_{ab} values for each patch, based on the L*, a*, b* coordinates.

The global $\overline{\Delta E^*_{ab}}$ for all the samples was evaluated against the reference. Then a colorimetric scale was build based on the global $\overline{\Delta E^*_{ab}}$ values of the samples.

Step 6: Psychometric-Colorimetric Correlation

Based on the visual scales from step 3 (lower and higher range of lightness values), and the colorimetric scale from step 4, a classical seven-step hypothesis-testing procedure was applied, as shown in Figure No. 12, and given in Sanders, 1995.

As was discussed in the hypothesis chapter, the null Hypothesis (**H0**) is that there is no relationship between the color matching scaled by the psychometric experiment and by the colorimetric evaluation (lightness value range 0-50 units for hypothesis $\mathbf{H0}_1$, and

50-100 units for hypothesis **$H0_2$**). The alternative hypothesis (**H1**) will be that there is a relationship when matching colors.

Figure No. 12. The classical seven-step hypothesis-testing procedure applied

Step 1: State the Null and Alternative Hypotheses	The assumption to be tested and the conclusion that is accepted
Step 2: Select the Level of Significance	The minimum acceptable probability of occurrence for a difference between parameters
Step 3: Determine the Test Distribution to Use	
Step 4: Define the Rejection or Critical Regions	Part of the sampling distribution that is specified as being unlikely
Step 5: State the Decision Rule	Formal statement of the appropriate conclusion to be reached
Step 6: Make the Necessary Computations	Conversion of the difference between parameters into a standardized value
Step 7: Make a Statistical Decision	If the standardized value falls into a rejection region, the null hypothesis is rejected

The classical seven-step hypothesis-testing procedure was carried out based on the hypotheses **H0** & **H1**, with a level of significance (α) equal to 95%. At that moment, a formal decision rule was stated as reject **H0** and fail to reject **H1** if the test ratio is higher than its critical value. The test ratio was calculated from a table built with both visual scales and the colorimetric scale (see Figure No. 12).

Step 7: ΔE^*_{ab} Distribution Study

Once the patches had been evaluated, and the relationship between visual scale and colorimetric scale had been tested, a ΔE^*_{ab} Distribution study was conducted. The study was based on the color differences between the reference color gamut and the digital color proof gamut to determine the degree of color match between the reference and the digital proof. The procedure is described in Figure No. 14. A scale for the color match was built based on the ΔE^*_{ab} Distribution statistics, basically, using a critical threshold of the slope of the cumulative relative frequency distribution curves of ΔE^*_{ab}.

The analysis was based on the assumption that the ΔE^*_{ab} Distribution more accurately predicts the visual match between proofs and the press sheet.

Figure No. 13. Psychometric-Colorimetric Correlation
Test of the Hypotheses

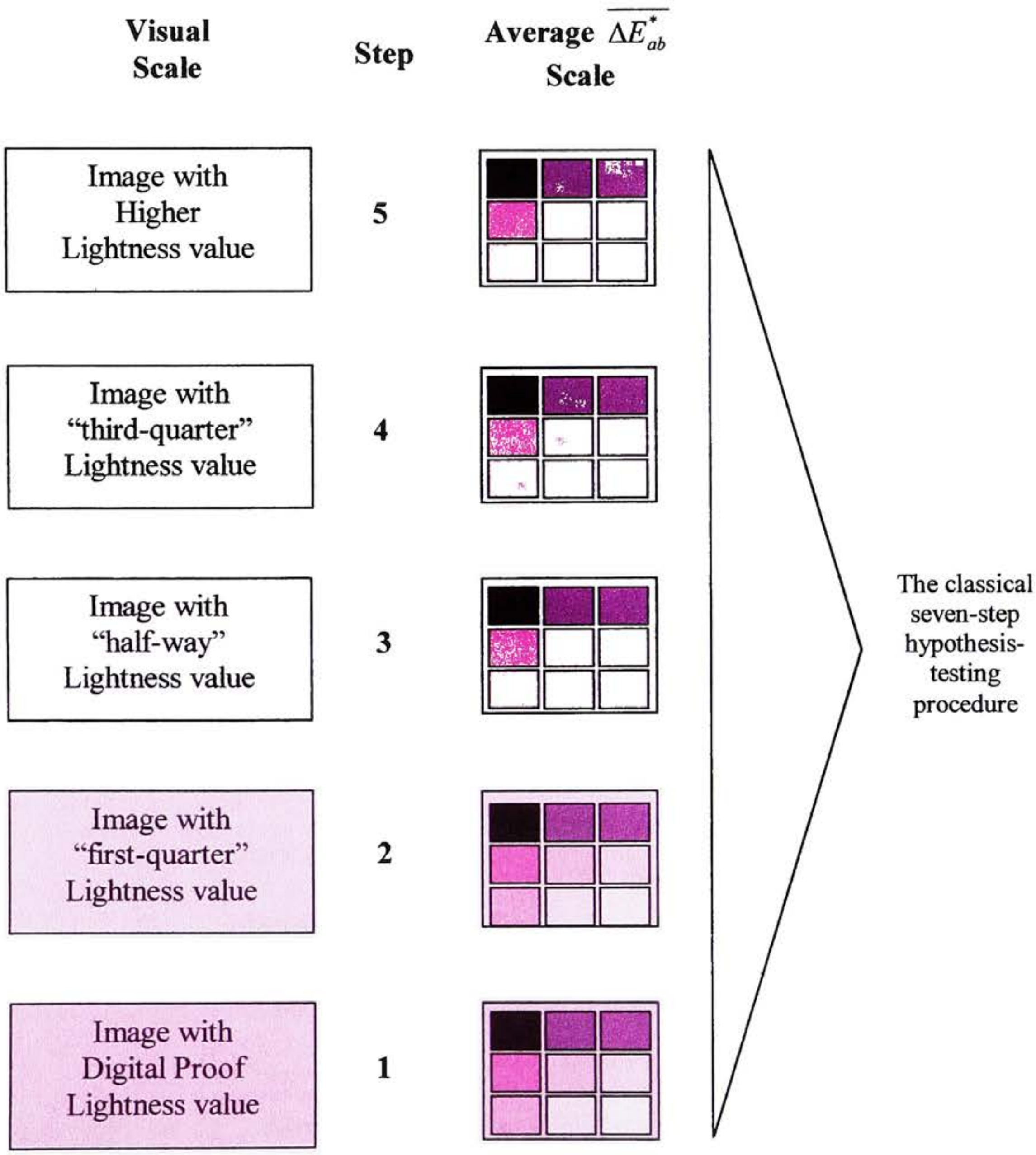


Figure No. 14. ΔE^*_{ab} Distribution procedure

1) Evaluation of ΔE^*_{ab}
2) Evaluation of absolute frequency, as the number of evaluated ΔE^*_{ab} with a certain class of evaluated ΔE^*_{ab} values.
3) Evaluation of frequency distribution.
4) Evaluation of relative frequency distribution, representing the absolute frequency and the total number of evaluated ΔE^*_{ab}.
5) Order and list the relative frequency distribution values in ascendant order.
6) Evaluation of cumulative relative frequency (CRF) distribution, as the cumulative sum in the ascendant list created before.
7) Plot CRF versus ΔE^*_{ab} classes.
8) Mark the visual scale.
9) Identify the critical value.
10) Establish conclusions.

An example of ΔE^*_{ab} distribution table and CRF distribution plot are shown in Appendix K.

Chapter 6

The Results

The pre-experimentation

A device consistency test and a material stability test were conducted prior to performing this research. The methodology of the test is described in Chapter 5. The colorimetric data gathered were processed in an Excel template to get a reference value set averaging all the sample values. The ΔE^*_{ab} was evaluated between each sample value and the evaluated reference. The color difference values are shown in Figure No. 15 and Table No. 2. The average ΔE^*_{ab} of 0.35 is practically small when contrasted against a real ΔE^*_{ab} between two press runs [1]. Therefore, the Epson SC 3000 was determined to be consistent device as shown before (Chan, 1999).

The material stability test was conduced as described in Chapter 5, and the results are shown in Figure No. 16 and Table No. 3. As different from that done in a research over the same proofer [1], the substrate used in this research was the Epson Photo Quality Glossy Paper, but the results on this material stability test are very similar. In addition, it appears that greater stability is successful in the one-two hour range. Therefore, the information derived from the period between two and four hours after printing is good for usage.

Figure No. 15. Average ΔE^*_{ab} of device consistency test

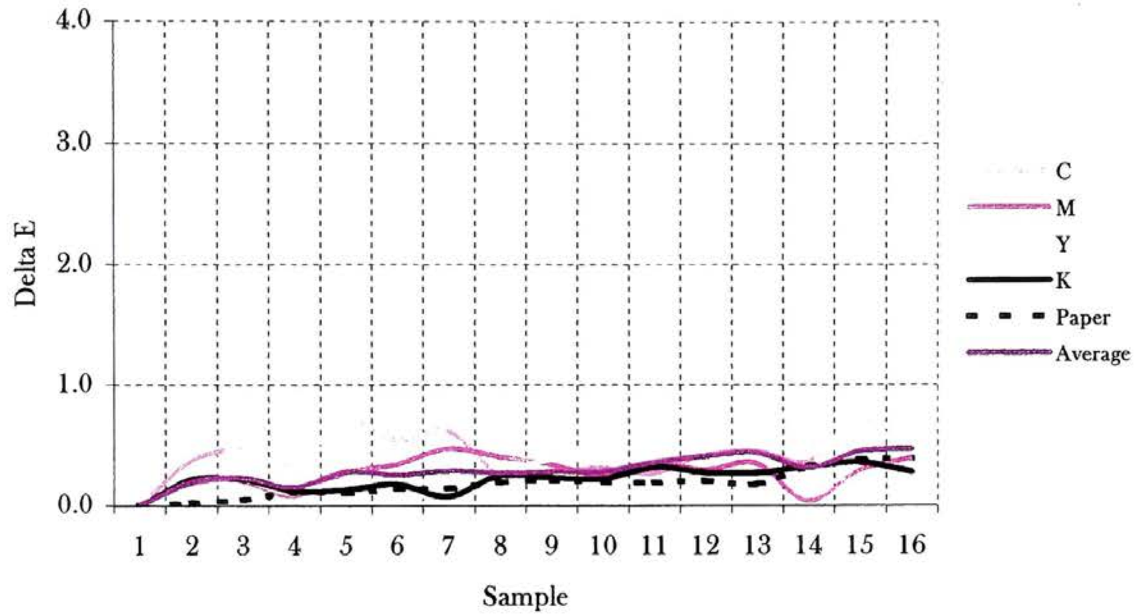


Table No. 2. Statistics of device consistency test

Total patches	2,912
Average ΔE^*_{ab}	0.32
Standard Deviation	0.23
Maximum ΔE^*_{ab}	2.54
Minimum ΔE^*_{ab}	0.01
Patches with $\Delta E^*_{ab} > 1$	47
Percentage	1.61
Patches with $\Delta E^*_{ab} > 2$	4
Percentage	0.14

Figure No. 16. ΔE^{*}_{ab} of material stability test

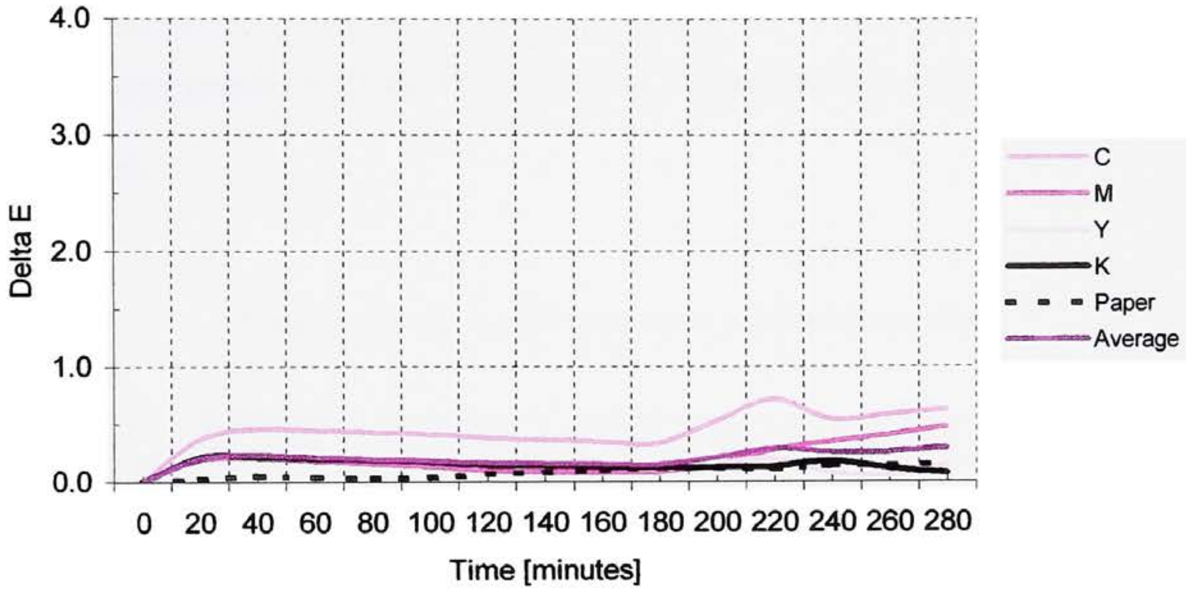


Table No. 3. Statistics of material stability test

Total patches	1,274
Average ΔE^{*}_{ab}	0.18
Standard Deviation	0.16
Maximum ΔE^{*}_{ab}	1.99
Minimum ΔE^{*}_{ab}	0.01
Patches with $\Delta E^{*}_{ab} > 1$	10
Percentage	0.78
Patches with $\Delta E^{*}_{ab} > 2$	0
Percentage	0.00

The psychometric experiment

The psychometric experiment was conduced as described in Chapter 5, and the test images described in Chapter 2 were used. The results are shown in Table No. 4 for 19 observers tested. The data showed a high consistency that was verified testing the same observer (one person) two times. For this reason, these judgments were omitted from the visual scale.

Table No. 4. Observer's judgments for the Visual scale

Observer	**Scale steps of Observer's judgments**								
No.	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**
1	50	40	25	15	0	-20	-30	-40	-50
2	50	35	20	10	0	-20	-30	-40	-50
3	50	35	20	10	0	-25	-30	-40	-50
4	50	35	20	10	0	-20	-30	-40	-50
5	50	40	25	15	0	-20	-30	-35	-50
6	50	35	20	10	0	-20	-30	-40	-50
7	50	35	20	10	0	-15	-30	-40	-50
8	50	40	25	20	0	-20	-30	-35	-50
9	50	35	20	10	0	-20	-25	-40	-50
10	50	35	20	10	0	-20	-30	-40	-50
11	50	35	15	5	0	-25	-35	-40	-50
12	50	35	20	10	0	-20	-35	-40	-50
13	50	35	15	5	0	-20	-30	-40	-50
14	50	35	20	5	0	-20	-30	-40	-50
15	50	40	25	10	0	-20	-30	-40	-50
16	50	35	15	10	0	-30	-35	-40	-50
17	50	35	20	10	0	-25	-30	-35	-50
18	50	40	25	10	0	-20	-25	-35	-50
19	50	35	20	5	0	-20	-30	-40	-50
Average	50.0	36.3	20.5	10.0	0.0	-21.1	-30.3	-38.9	-50.0
Stdev	0.0	2.3	3.3	3.7	0.0	3.2	2.6	2.1	0.0

From left to right, both five-step scales are listed. At left the higher lightness value scale (light area), and at right the lower lightness scale (dark area). The evaluation of the color difference for each Observer's judgment was done using ΔE^*_{ab} (metric) scale shown in Appendix I. Every visual test selected by an observer was match with the lightness value, and ΔE^*_{ab} value was picked up. The results are shown in Table No. 5.

Table No. 5. Observer's judgments transformed to Delta E equivalent value.

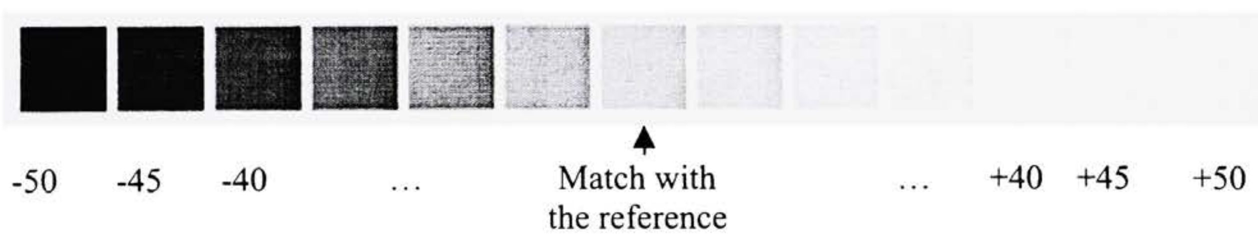
Observer	**Delta E equivalent value**								
No.	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**
1	15.8	13.5	8.6	5.0	0.0	8.5	12.5	16.9	20.9
2	15.8	11.7	7.1	3.3	0.0	8.5	12.5	16.9	20.9
3	15.8	11.7	7.1	3.3	0.0	10.5	12.5	16.9	20.9
4	15.8	11.7	7.1	3.3	0.0	8.5	12.5	16.9	20.9
5	15.8	13.5	8.6	5.0	0.0	8.5	12.5	14.7	20.9
6	15.8	11.7	7.1	3.3	0.0	8.5	12.5	16.9	20.9
7	15.8	11.7	7.1	3.3	0.0	6.2	12.5	16.9	20.9
8	15.8	13.5	8.6	7.1	0.0	8.5	12.5	14.7	20.9
9	15.8	11.7	7.1	3.3	0.0	8.5	10.5	16.9	20.9
10	15.8	11.7	7.1	3.3	0.0	8.5	12.5	16.9	20.9
11	15.8	11.7	5.0	2.0	0.0	10.5	14.7	16.9	20.9
12	15.8	11.7	7.1	3.3	0.0	8.5	14.7	16.9	20.9
13	15.8	11.7	5.0	2.0	0.0	8.5	12.5	16.9	20.9
14	15.8	11.7	7.1	2.0	0.0	8.5	12.5	16.9	20.9
15	15.8	13.5	8.6	3.3	0.0	8.5	12.5	16.9	20.9
16	15.8	11.7	5.0	3.3	0.0	12.5	14.7	16.9	20.9
17	15.8	11.7	7.1	3.3	0.0	10.5	12.5	14.7	20.9
18	15.8	13.5	8.6	3.3	0.0	8.5	10.5	14.7	20.9
19	15.8	11.7	7.1	2.0	0.0	8.5	12.5	16.9	20.9
Average	15.8	12.2	7.2	3.4	0.0	8.9	12.6	16.4	20.9
Stdev	0.0	0.8	1.2	1.2	0.0	1.3	1.1	0.9	0.0

Colorimetric evaluation

Using ΔE^*_{ab} equivalent values (from Table No. 5) for the observer's judgments to build the visual scale, and plotting the lightness scale versus this visual scale with the Average ΔE^*_{ab} scale and the ΔE^*_{94} values together, a graphical representation of their relationships can be observed, as shown in Figure No. 17 and Table No. 6. The color difference ΔE^*_{94} was evaluated with the parametric factors and weighting functions described in Chapter 2: Theoretical Bases of the Study.

In this figure, a schematic plotting has been used as follows: from left to right, the lower lightness value (the lower value of the dark area) to the higher lightness value (the higher value of the light area); negative values for lightness has been assigned for those lightness values of the lightness axis on the dark area.

The lightness axis is a representation of the gray patches used for the psychometric experiment and described in Chapter 5: Methodology, as follows in a schematic way:



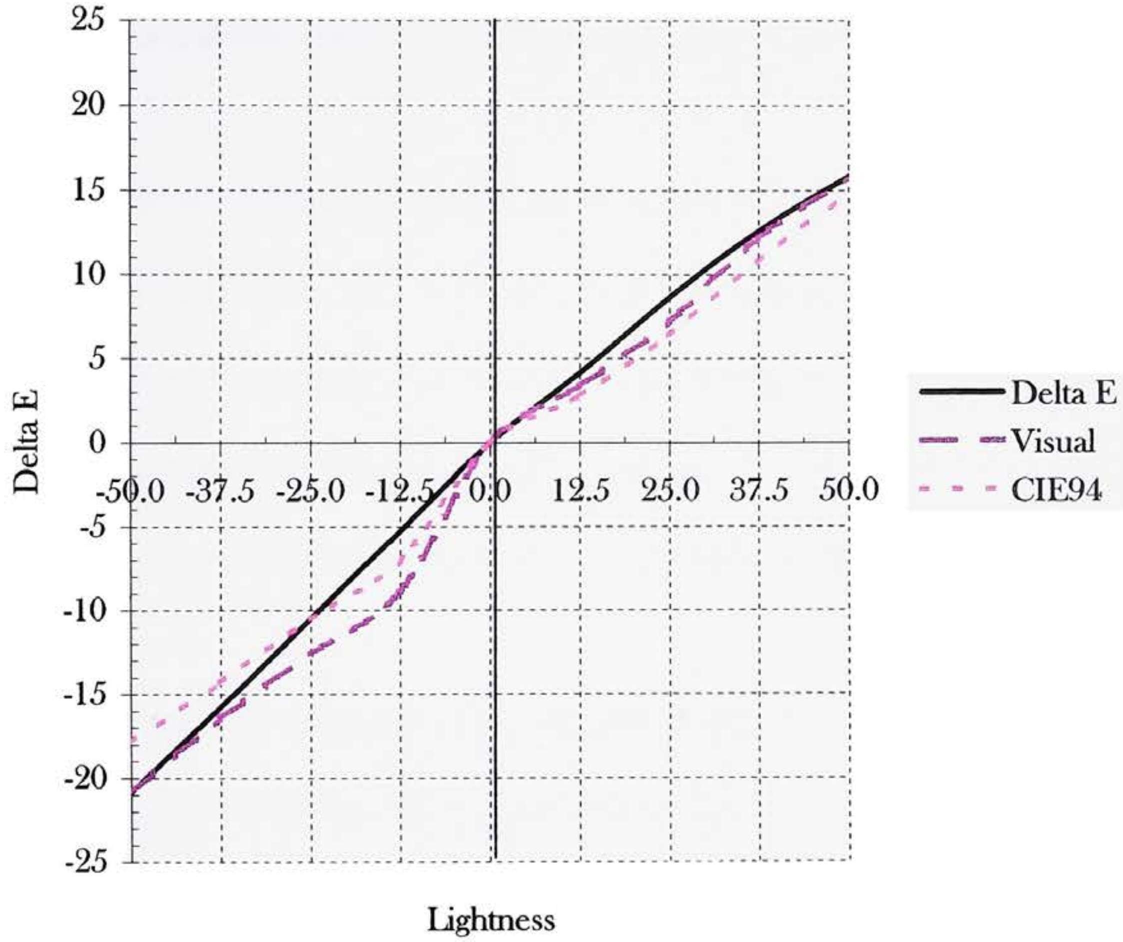
A sorted table for both lightness ranges, from light to dark, is shown in Table No. 6, where the common step (No. 1) is the match point with the reference gray patch. The scales were built as described in Chapter 5: Methodology; and briefly described as follows: The visual scale was built based on the Partition Judgments. The test images used for those judgments were differentiated by different lightness values around the digital proof lightness value, with the same distance on both sides of the lightness scale. In the Appendix H is described the method used to create the different lightness values based on the Kodak Color*flow* Profile Editor Color tools.

The metric scale for $\overline{\Delta E^{*}_{ab}}$ was built using the evaluation of ΔE^{*}_{ab} for each patch and averaging over 182 patches. The ΔE^{*}_{ab} is evaluated by the sum of the squared differences between the variables L*, a*, and b*. In Appendix D the data measured from each proof sample considered in the visual scaling technique are shown.

Table No. 6. Visual, $\overline{\Delta E^{*}_{ab}}$ and ΔE^{*}_{94} scales for both lightness ranges
(Light area is equal to higher range, and dark area is equal to lower range)

Step	Visual Scale	$\overline{\Delta E^{*}_{ab}}$ Scale	ΔE^{*}_{94} Scale
5	15.81	15.81	14.82
4	12.17	12.59	10.75
3	7.20	8.63	6.36
2	3.39	4.15	2.74
1	0.00	0.00	0.00
2	-8.88	-5.29	-7.09
3	-12.63	-10.47	-10.53
4	-16.39	-15.76	-14.27
5	-20.85	-20.85	-17.84

Figure No. 17. Color difference versus Lightness for ΔE^*_{ab} (Delta E) scale, Visual scale and CIE94 (ΔE^*_{94}) scale



The research: psychometric-colorimetric correlation

This study was based on the color difference formulae ΔE^*_{ab} proposed by the Commission International de L'Eclairage (CIE), the ICC-based CMS, and the Psychometric technique described in Chapter 5. Based on those statements, two testing procedures and the further analysis were conducted and their results are shown in the next sections.

The interpretation of the color difference ΔE^*_{ab} has being used as the difference between the spatial position of a color (sample) and the spatial position of the reference color. In Appendix I the evaluation of the visual scale, the $\overline{\Delta E^*_{ab}}$ scale, and ΔE^*_{94} scale, is described.

The process of verification of mismatching between the visual scale and the colorimetric scale based on $\overline{\Delta E^*_{ab}}$ in digital proofing, was done using the hypotheses stated in Chapter 4: The Hypotheses. The hypothesis testing procedure between the visual scale and the colorimetric scale based on $\overline{\Delta E^*_{ab}}$ using the "t" Test described in Chapter 5: Methodology, Step 6: Psychometric-colorimetric correlation, and Appendix J as specific application.

In spite of the ΔE^*_{ab} distribution does not conform to the assumption of Gaussian distribution in the "t" Test, this test is used in this research to help understand the observed visual scale variations when compared against the colorimetric scale.

Testing hypothesis procedure for $H0_2$. A sorted table for higher lightness value range is shown in Table No. 7. Those values are used as $\overline{\Delta E^*_{ab}}$ values in this procedure. A "t" Test of the hypothesis that there is no relationship between the visual scale and the colorimetric scale when using the average of CIELAB $\overline{\Delta E^*_{ab}}$ color difference in ICC-based CMS for lightness values in between 50 and 100 units was applied. The seven-step

Table No. 7. Visual and $\overline{\Delta E^*_{ab}}$ scales for higher lightness range

	Visual Scale	$\overline{\Delta E^*_{ab}}$ Scale
5	15.81	15.81
4	12.17	12.59
3	7.20	8.63
2	3.39	4.15
1	0.00	0.00

Table No. 8. "t" Test results for higher lightness range

Step	Description
1	$H0_2$: $\mu_{Visual} = \mu_{\Delta E^*}$ $H1_2$: $\mu_{Visual} \neq \mu_{\Delta E^*}$
2	$\alpha = 0.025$
3	"t" Distribution
4	df = 18 $t_{(18,0.025)} = 2.101$
5	Reject $H0_2$ and accept $H1_2$ if $\mu_{\Delta E^*} < (\mu_{visual} - t\sigma)$ or $\mu_{\Delta E^*} > (\mu_{visual} + t\sigma)$ Otherwise, Fail to Reject $H0_2$
6	$\mu_{\Delta E^*}$ and μ_{visual} are shown in Table No. 7
7	Fail to Reject $H0_2$

Testing hypothesis procedure for $\mathbf{H0_1}$. A sorted table for lower lightness value range is shown in Table No. 9. Those values are used as μ values in this procedure. A "t" Test of the hypothesis that there is no relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 0 and 50 units was applied. The seven-step hypothesis-testing procedure described in Chapter 5 was conducted and the results are summarized in Table No. 10. From there, the color mismatch was verified when the null hypothesis $\mathbf{H0_1}$ was rejected. Therefore, a different color matching evaluation must be applied.

ΔE^*_{ab} Distribution study

To apply a different color matching evaluation, the further analysis was conducted using a cumulative relative frequency distribution of ΔE^*_{ab} values, as described in Chapter 5: Methodology. The assumption of another distribution, different from Gaussian, of IT8.7/3-based color differences between the reference and the digital proof helps in the study of color mismatching as can be appreciated from the sorted tables shown above.

Table No. 9. Visual and $\overline{\Delta E^*_{ab}}$ scales for lower lightness range

	Visual Scale	$\overline{\Delta E^*_{ab}}$ Scale
5	-20.85	-20.85
4	-16.39	-15.76
3	-12.63	-10.47
2	-8.88	-5.29
1	0.00	0.00

Table No. 10. "t" Test results for lower lightness range

Step	Description
1	$H0_1$: $\mu_{Visual} = \mu_{\Delta E^*}$ $H1_1$: $\mu_{Visual} \neq \mu_{\Delta E^*}$
2	$\alpha = 0.025$
3	"t" Distribution
4	df = 18 $t_{(18,0.025)} = 2.101$
5	Reject $H0_1$ and accept $H1_1$ if $\mu_{\Delta E^*} < (\mu_{visual} - t\sigma)$ or $\mu_{\Delta E^*} > (\mu_{visual} + t\sigma)$ Otherwise, Fail to Reject $H0_1$
6	$\mu_{\Delta E^*}$ and μ_{visual} are shown in Table No. 9
7	Reject $H0_1$

The ΔE^{*}_{ab} values for the cumulative relative frequency distribution are plotted in Figure No. 18 for the higher lightness range (light area), and in Figure No. 19 for the lower lightness range (dark area).

Figure No. 18. Cumulative relative frequency (CFR) distribution for ΔE^{*}_{ab} values of the higher lightness range (light area)

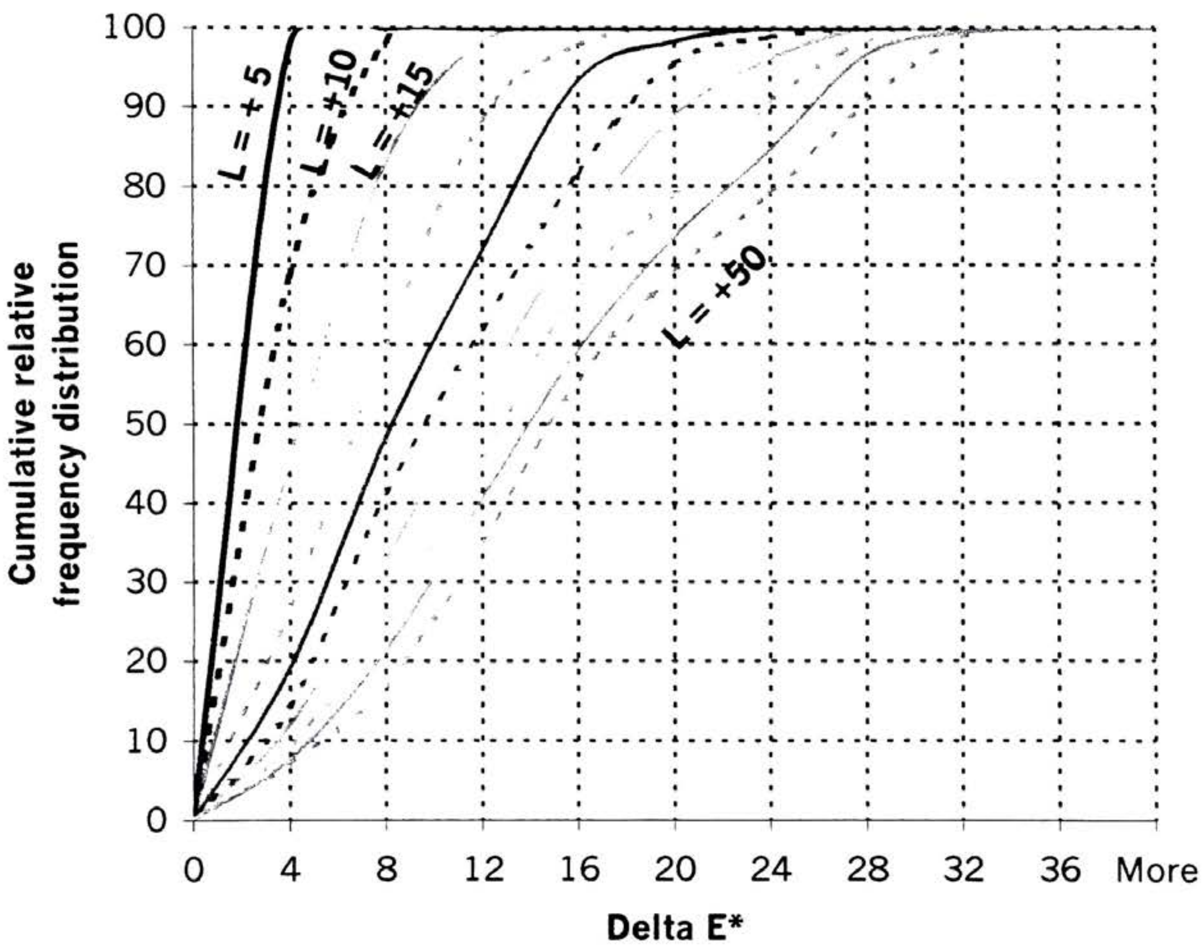
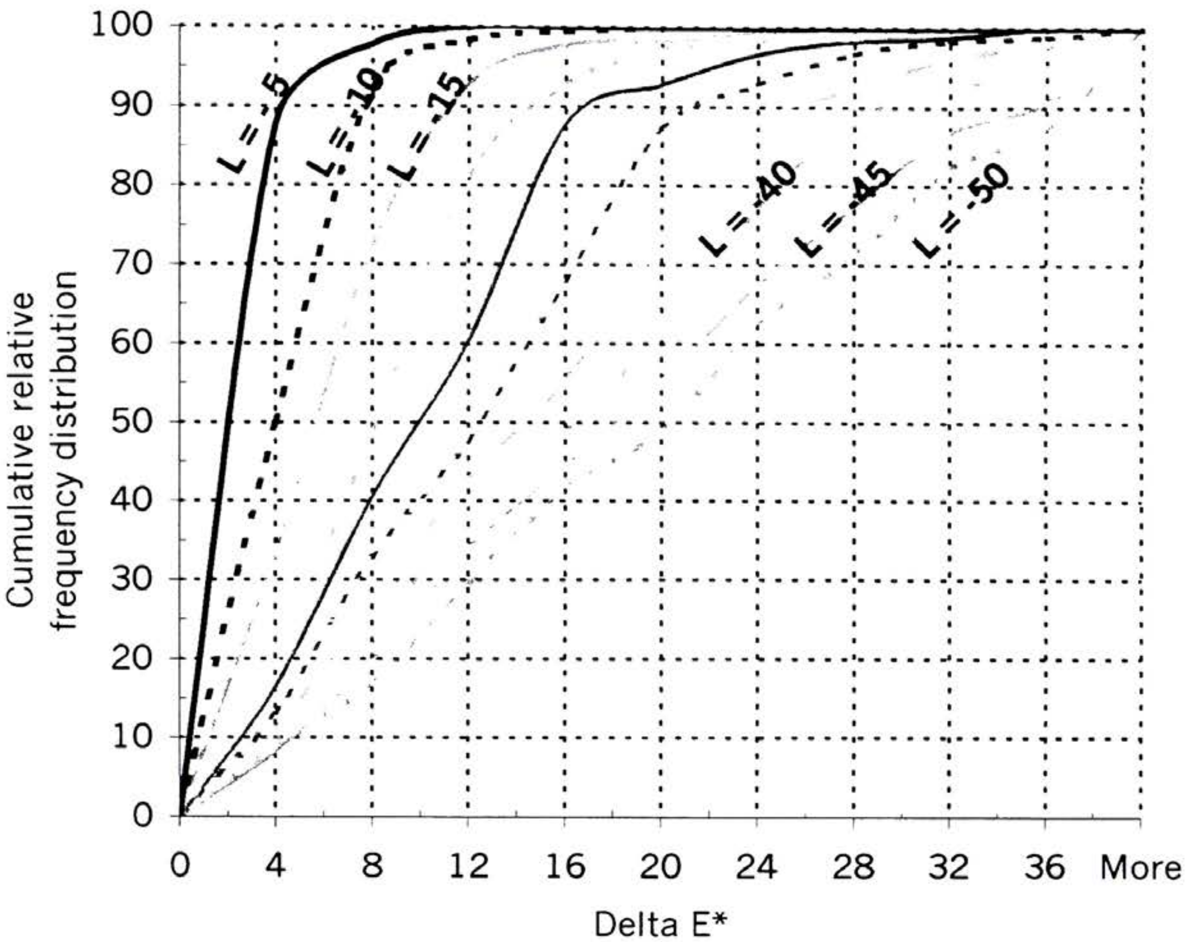


Figure No. 19. Cumulative relative frequency (CRF) distribution for ΔE^{*}_{ab} values of the lower lightness range (dark area)



As can be seen, the cumulative relative frequency distributions for higher lightness range are more vertical than those for the lower lightness range. This difference can be related with the observed differences from the Figure No. 17, where the curves are parallels for the higher lightness range, but not for the lower lightness range.

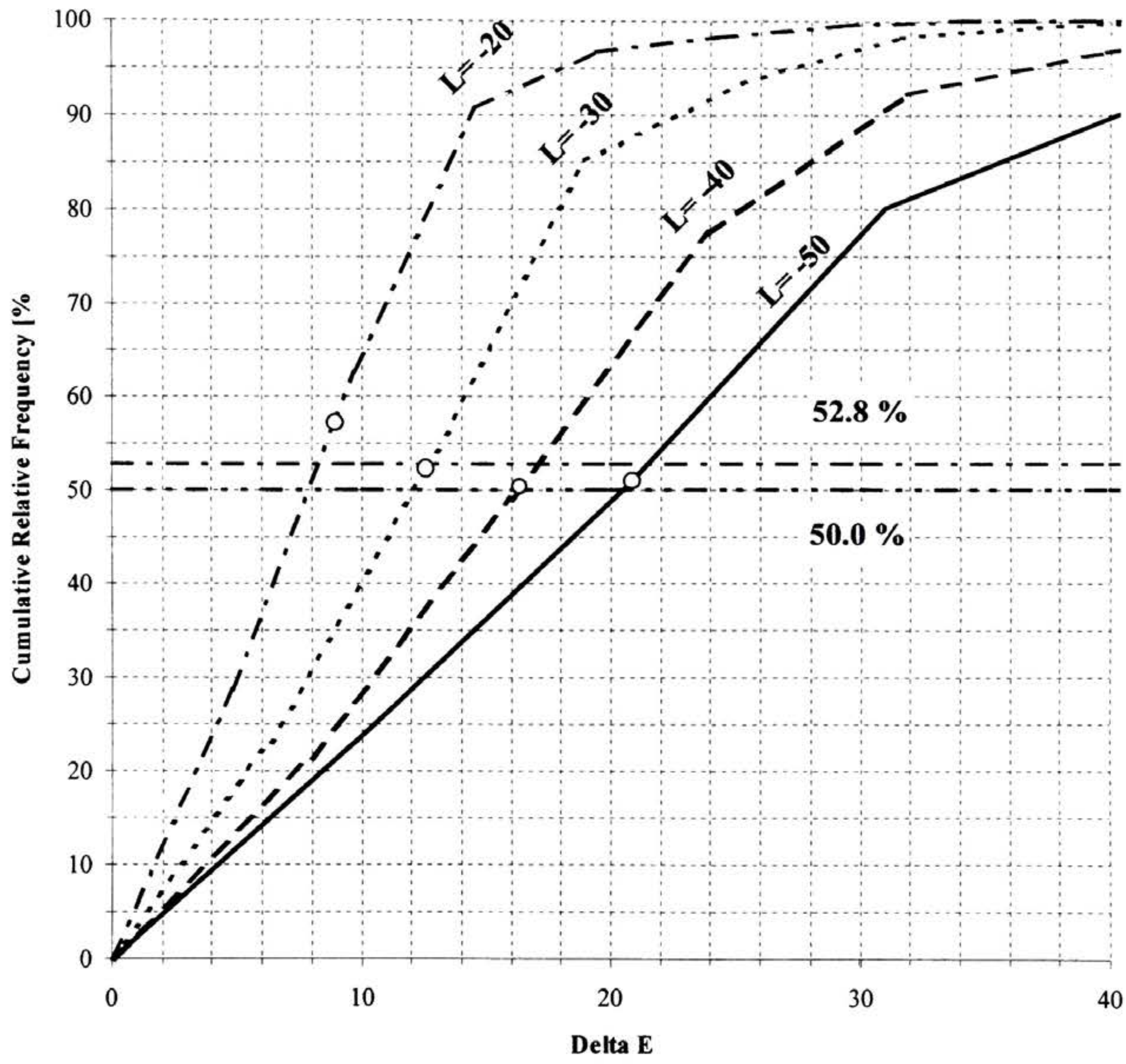
The critical case is the dark area, lower lightness range, where the curve of the visual scale and the curve of the metric scale (ΔE^*_{ab} scale) are not parallels, as can be observed in the Figure No. 17. The curve of the visual scale is following the curve of the ΔE^*_{94} scale, whose shape is not a straight line.

Analyzing this case by the cumulative relative frequency (CRF) distribution of ΔE^*_{ab} values, for the scales given before, a plot of the cumulative curves and the visual scale can be obtained, as shown in Figure No. 20. The figure shows only the step curves of CRF for the lower lightness range (-20, -30, -40, and –50), where the color mismatch problem is higher.

From this figure, a critical value of CRF equal to 52.8% looks like a better approach for the evaluation of the color differences than the average of ΔE^*_{ab}. In spite of that each step curve (-20, -30, -40, and –50) has its own critical value, the global critical value has been selected as the average of the Visual scale with values in equivalent metric color difference. The line for 50% shown is the equivalent to the average of ΔE^*_{ab} that is used by recommendation of CIE.

From this research, the critical value shown above is appropriate to describe how visual perception linearity correlate with measured differences.

Figure No. 20. Cumulative relative frequency distribution for ΔE^{*}_{ab} values of the lower lightness range (dark area) with the visual scale



From this analysis, the improved color match of the ICC-based CMS was tested, and concluded that fixing a critical value in the frequency distribution of ΔE^{*}_{ab} curves, a better color matching evaluation can result. With this new method, another important step in the digital proofing technology application has been done.

Endnotes for Chapter 6

1. Chan, C. Joel. "A Study of Matching the Color of EPSON Stylus COLOR 3000 to ANSI CGATS TR 001-1995 – Type 1 Printing." Master Thesis RIT, April 1999

2. Bartels, Sharon, and Richard Fish. "A Colorimetric Test for Reflection CMYK Colorant Output." TAGA Proceedings 1999, pp. 204-215

Chapter 7

Summary and Conclusions

The performance of color matching in ICC-based Color Management Systems (CMS) may be improved using the ΔE^*_{ab} Distribution method used in this research. In the case of digital proofing, to evaluate the degree of color matching between a reference image and a sample image, the $\overline{\Delta E^*_{ab}}$ calculated average of the individual color differences is being used as a matching scale, but as shown here, ΔE^*_{ab} Distribution method may be a better way to evaluate it.

In the digital proofing workflow, the global $\overline{\Delta E^*_{ab}}$ evaluation has been taken as valid. However, this assumption had being questioned here concluding that it may be better to consider a distribution to achieve an accurate determination of color matching.

In this research, the objective was to study two aspects of a CMS performance:

(1) The assumption of mismatch between the $\overline{\Delta E^*_{ab}}$ and the perceptual scaling,

(2) The degree of color matching in digital proofing using the ΔE^*_{ab} Distribution process instead of the average $\overline{\Delta E^*_{ab}}$.

The assumption of another distribution, different from Gaussian, of IT8.7/3-based color differences between the press sheet and the digital proof helps in the study of color mismatching.

This study was based on the color difference formulae ΔE^*_{ab} proposed [1] by the Commission International de L'Eclairage (CIE), the ICC-based CMS, and the Psychometric technique.

The interpretation of the color difference ΔE^*_{ab} has being used as the difference between the spatial position of a color (sample) and the spatial position of a reference color. The evaluation of ΔE^*_{ab} is done by the sum of the squared differences between the variables L*, a*, and b*. These square differences imply that ΔE^*_{ab} holds only positive values, although these positive values may follow an asymmetrical distribution.[11,12] Here, the study of the ΔE^*_{ab} Distribution as matching scale was shown to improve evaluation of the accuracy of the performance of the digital proofing color matching. The scale for the color match was built based on the ΔE^*_{ab} Distribution statistics, basically, using the slope showed by a graph of the relative frequency distribution of the ΔE^*_{ab} curve.

The Psychometric technique was used to create a visual scale based on a scaling method called Partition Judgments. The test images used were differentiated by different lightness values around the digital proof profile lightness value, with the same distance on both sides of the lightness scale. The panel of observers was selected through a color defective or normal color vision test: the FM 100 H Test.

Based on the need to verify the mismatching between the visual scale and the colorimetric scale in digital proofing, this research had two main hypotheses stated in Chapter 4: The Hypotheses. The first pair of hypotheses (**H$_1$**) was tested by a non-parametric analysis between the visual scale and the colorimetric scale based on $\overline{\Delta E^*_{ab}}$. From this statistical analysis, the improved color match of the ICC-based CMS was tested, and concluded that the null hypothesis **H0$_1$** was rejected. In other words, there is no relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference for lightness values in between 0 and 50 units. Therefore, a different color matching evaluation must be applied when doing digital proofing over the dark area of the Epson Stylus™ Color 3000 gamut.

The second pair of hypotheses (**H$_2$**) was tested by a non-parametric analysis between the visual scale and the ΔE^*_{ab} Distribution scale. From this statistical analysis, the color mismatch was verified when the null hypothesis **H0$_2$** failed to be rejected. In other words, there is a relationship between the visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference for lightness values in between 50 and 100 units. Therefore, the proposed ICC-based CMS color matching evaluation must be applied when doing digital proofing over the light area of the Epson Stylus™ Color 3000 gamut.

Recommendations for Further Investigation

Further analysis may require the use of different devices or methodologies as follows.

Use of an alternative digital proofing technology. Further analysis may require the use of an alternative digital proofing technology to discern whether this methodology of ΔE^*_{ab} Distribution provides more insight into the performance of color matching in digital proofing by ICC-based CMS.

Use of weighting functions. Further analysis may require studying the correlation between qualitative and quantitative color matching through weighting functions. Based on statistics and graphical analyses of the CIELAB values for five specific groups, weighting functions can be used to improve evaluation of color matching in digital proofing. Namely, the CIELAB values analysis should be conducted over the 182 patches assembled in, at least, neutral, pastel, and special colors groups.

Use of any other dimension in the color space. The scaling experiment used here was based on the test images differentiated by different lightness values around the digital proof profile lightness value, with the same distance on both sides of the lightness scale. Further analysis may require the use of an alternative dimension in the color space used (CIELAB) to discern whether this methodology of ΔE^*_{ab} Distribution provides more insight into the performance of color matching in digital proofing by ICC-based CMS.

Glossary

Glossary

Accuracy. "n – the closeness of agreement between a test result and an accepted reference value. (1993). *Discussion* – The qualitative term accuracy, when applied to a set of observed values, will be a combination of a random precision component and a systematic error or bias component. Since in routine use random components and bias components cannot be completely separated, the reported 'accuracy' must be interpreted as a combination of these two elements"[2]

Achromatic. "In accepted colorimetric sense: 1. For primary light source, the colour of the equi-energy spectrum ($x = y = z = ⅓$) is taken as achromatic. 2. For surface colours the light source serving as illuminant is taken as achromatic. *Note*. On this basis, an ideal white surface is always defined as achromatic whatever may be the colour of the light."[1]

ANSI. Acronym for American National Standard Institute.

API. "Acronym for Application Program Interface; for example, a feature in ColorSync 2.0 which provides color matching functions to application software using standard architecture and profile format without the need to develop custom routines."[3]

ASTM. Acronym for American Society for Testing and Materials.

Calibrate. "v – to find and eliminate systematic errors of an instrument scale or method of measurement by use of material standards and techniques traceable to an authorized national or international measurement system. (1994a)"[2]

Calibration. "Adjustment of a device to know values; in open systems approach to color reproduction, each and every device must be calibrated to ensure modularity and connectivity."[3]

CGATS. Acronym for Committee for Graphic Arts Technologies Standards.

Characterization. "Use of test targets, color measurement, and computer programs to determine the input and output relationship of an imaging device."[3]

Characterize. "v – to specify the parameters or performance of an instrument or method of measurement. (1994)"[2]

Chroma. "n – (1) attribute of color used to indicate the degree of departure of the color from a gray of the same lightness.... (2) C*, (in the CIE 1976 L*, a*, b* ... system) the quantity $C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$ .... (1989b). (3) attribute of a visual perception, produced by an object color, that permits a judgment to be made of the amount of pure chromatic color present, irrespective of the amount of achromatic color. (1995)"[2]

Chromaticity coordinates. "n – the ratio of each of the tristimulus values of any viewed light to the sum of the three. (1995)"[2]

Chromaticity diagram. "n – a plane diagram in which points specified by chromaticity coordinates represent the chromaticities of light (color stimuli).(1995)"[2]

Chromaticity. "Colour quality of a colour stimulus definable by its chromaticity coordinates, or by its dominant (or complementary) wavelength and its purity taken together."[1,2]

CIE standard colorimetric observer. "Receptor of radiation whose colorimetric characteristics correspond to the spectral tristimulus values $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ adopted by the International Commission on Illumination in 1931."[1]

CIE standard illuminants. "The colorimetric illuminants A, B, C and D_{65}, defined by the C.I.E. in terms of relative spectral energy [power] distribution: **standard illuminant A**, representing the full radiator at T_{68} = 2 855.6 K; **standard illuminant B**, representing direct sunlight with a correlated colour temperature of T_{68} = 4 874 K; **standard illuminant C**, representing daylight with a correlated colour temperature of T_{68} = 6 774 K; **standard illuminant D_{65}**, representing daylight with a correlated colour temperature of T_{68} = 6 504 K."[1]

CIE. "n – the abbreviation for the French title of the International Commission on Illumination, Commission Internationale de l'Eclairage."[2,3]

CIELAB color difference. "n – color difference calculated by using the CIE 1976 L* a* b* opponent-color scales, based on applying a cube-root transformation to CIE 1931 tristimulus values X, Y, Z .... (1988)"[2]

CIELAB color space. "The color space comprises lightness axis L*, the red/green axis a*, and the yellow/blue axis b*. It models how humans perceive color."[3]

CMS. "Short for color management system; software/hardware system used to ensure color consistency among different input and output devices."[3]

CMYK. "Abbreviation for color cyan, magenta, yellow, and black (the K also stands for key, meaning black)."[3]

Color difference. "n – (1) *perceived*, the magnitude and character of the difference between two colors described by such terms as redder, bluer, lighter, darker, grayer, or cleaner. (2) *Computed*, the magnitude and direction of the difference between two psychophysical color stimuli and their components computed from tristimulus values, or chromaticity coordinates and luminance factor, by means of a specified set of color-difference equations."[2]

Color management module. (CMM) A math processor to realize a color transformation required between two device profiles and a profile connection space (PCS).[5]

Color match. "n – (1) condition existing when colors match within a specified or agreed tolerance. Sometimes called *commercial color match*. (1988a) DISCUSSION – Compliance with tolerances can be determined instrumentally or visually. If the test for compliance is visual, physical color tolerance standards may be used for reference. (2) Condition existing when colors are indistinguishable; a normal observer is usually implied. Sometimes called an *exact color match*. (1988a)"[2]

Color matching. "n – procedure for providing, by selection, formulation, adjustment, or other means, a trial color that is indistinguishable from, or within specified tolerances of, a specified standard color under specified conditions. (1988a)"[2]. "*Note*. The French and Russian terms apply mainly to the adjustment to equality of the fields of a visual colorimeter, whereas the English and German terms apply equally well to the selection of two material specimens having the same colour."[1]

Color reproduction. There are six different types of color reproduction [8] as follows: *spectral*, the equality of spectral reflectance factors or relative spectral radiances; *colorimetric*, the equality of chromaticities and relative luminances; *exact*, the equality of chromaticities and absolute luminances; *equivalent*, the equality of appearance; *corresponding*, the equality of appearance when the original and reproduction luminance levels are the same; *preferred*, allows departures from equality of appearance to achieve a more pleasing result.

Colour gamut. "An area [volume] in a chromaticity diagram [colour space]. Usually that part of the chromaticity diagram [colour space] embracing all colours capable of being reproduced by a particular choice of parameters in a colour process."[1]

Colour rendering. "General expression for the effect of an illuminant on the colour appearance of objects in conscious or subconscious comparison with their colour appearance under a reference illuminant."[1]

Colour space. "Manifold of three dimensions for the geometrical representation of colours."[1]

Colour stimulus. "Physically defined radiation entering the eye and producing a sensation of colour."[1]

Colour UK*; color* USA. "1. **(perceived) colour**: Aspect of visual perception by which an observer may distinguish differences between two fields of view of the same size, shape and structure, such as may be caused by differences in the spectral composition of the radiation concerned in the observation. 2. **(psychophysical) colour**: Characteristic of a visible radiation by which an observer may distinguish differences between two fields of view of the same size, shape and structure, such as may be caused by differences in the spectral composition of the radiation concerned in the observation. *Note* 1. Psychophysical colour is specified by the tristimulus values of the radiation entering the eye.... *Note* 2. The adjectives *perceived* and *psychophysical* shown in parentheses are necessary only when the context does not clearly indicate whether the terms are used in the subjective or objective sense."[1]

Consistency. Color value printed agreement of a printer device with that which has been previously printed, manly on density value.

Critical value. Value used in this research to distinguish the color mismatch, shifting the argument of the evaluated color difference.

D50. Industry standard light source. The "D" stands for daylight and the "50" stands for the color temperature of the light in degrees Kelvin, 5000 K.[6]

D65. Industry standard light source. The "D" stands for daylight and the "65" stands for the color temperature of the light in degrees Kelvin, 6500 K.[6]

Device profile. File that has all the characteristics of the color reproduction of that device. The most used device profiles are input profile, monitor profile, and output profile.

Device-Independent color space. One of the three components of the CMS.

Digital proofing. Process to predict the appearance of a printed image. In the process a digital imaging device is used. CMYK-to-CMYK color conversion case.[4]

Distribution. Statement that facilitates the complete characterization of the random variable.[10] In the this research, frequency of occurrence of ΔE^*_{ab} values over the lightness scale (0 to 100 units) to show a major insight on the degree of color matching in digital proofing.

Euclidean space. Three-dimensional representation of a position vector or point, where the unit vectors are linearly independent.[10]

Gamut. Edge lines of analytically and empirically modeled color space of devices.

Gaussian distribution. Distribution of random variables (measured values), which can be regarded as the superposition of defective quantities of approximately equal strength. Also known as Normal Distribution.[10]

Hue. "n – the attribute of color perception by means of which a color if judged to be red, orange, yellow, green, blue, purple, or intermediate between adjacent pairs of these, considered in a close ring (red and purple being an adjacent pair.)"[2]

Hue-angle. Numerical specification of a hue.

ICC. Acronym for International Color Consortium.

Illuminant. "Radiant energy with a relative spectral energy [power] distribution defined over the wavelength range that influences object colour perception. *Note*. In English this term is not restricted to this sense, but is a general term used for any kind of light falling on a body or scene, and is also used to refer to the light source itself, including its filters if any."[1]

ISO. Acronym for International Organization for Standardization.

Lightness. "Attribute of visual sensation in accordance with which a body seems to transmit or reflect diffusely a greater or smaller fraction of the incident light. *Note*. This attribute is the psycho sensorial correlate, or nearly so, of the photometric quantity *luminance factor*."[1]

Match. "v – to provide, by selection, formulation, adjustment, or other means, a trial color that is indistinguishable from, or within specified tolerances of, a specified standard color under specified conditions. (1991)"[2]

Neutral. Black, white, or shades of gray. They represent degrees of light and dark, not color. In the RGB color space, neutrals are defined as having the same value for each color component. The lower the number, the darker the neutral.[7]

Normal color vision. Often called trichromat and refers to a person having the ability to sense or discriminate light from dark, red from green, and yellow from blue.[9]

Parametric factors. Variables k_L, k_C, and k_H used in the improved color difference equation shown in Chapter 2, to describe the color difference with recommended values of $k_L = 1$, $k_C = 1$, and $k_H = 1$. Robertson suggested to use $k_C = 2$.

Patches. Small image with uniform color to achieve very quick results when comparing or determining color differences.

Profile Connection Space. (PCS) One portion of the Device-Independent color that uses the tristimulus values (XYZ) or CIELAB.

Psychometric evaluation. Measurement of mental processes where the aptitude testing to help in color selection is included.

Reference conditions. Conditions or values used to compare or evaluate the color difference of a single color. Illumination, illuminance, viewing mode, and surround field are included.

Rendering styles. *perceptual*, *colorimetric* (relative and absolute), and *saturation* style. The *perceptual rendering style* (or intent) optimizes the image (appearance) quality, maintaining the color-to-color relationship, as the colors are mapped to the printer gamut, in spite of the fact that the color values can change. The *colorimetric rendering style* optimizes the accuracy of colors, and can be realized relative to the white point of the media, or absolute (white point of the standard). In the relative colorimetric case, the out-of-gamut colors are transformed to color that have the same lightness but fall just inside the gamut. In the *absolute colorimetric* case, the white point matching is disabled when converting the colors. The *saturation rendering style* maintains the saturation of colors. Thereby, the out-of-gamut colors are transformed to colors that fall just inside the gamut with the same saturation. Hue and lightness may lack accuracy.

Saturation. "Attribute of a visual sensation which permits a judgment to be made of the proportion of pure chromatic colour in the total sensation. *Note* 1. This attribute is the psycho sensorial correlate, or nearly so, of the colorimetric quantity *purity*."[1,2]

Spectral tristimulus values. "Tristimulus values, on any given colorimetric system, of the monochromatic components of an equi-energy spectrum. The set of spectral tristimulus values defines the **colour-matching functions** of **colour-matching curves**. *Note* 1. Formerly **distribution coefficients**. *Note* 2. The symbols used are small letters with a bar followed by the letter λ in parentheses; the letters chosen should correspond with those used for the reference stimuli...."[1]

Stability. Measures of how a color varies as a function of the time after printing.

SWOP. Acronym for Specification for Web Offset Publications.

TAGA. Acronym for Technical Association of the Graphic Arts.

TAPPI. Acronym for Technical Association of the Pulp and Paper Industry.

Tristimulus values "(of a colour stimulus). Amount of the three references of matching stimuli required to give a match with the colour stimulus considered, in a given trichromatic system.* *Note* 1. The symbols recommended for the tristimulus values are: X, Y, Z in the CIE 1931 standard colorimetric system.... *Note* 2. It is recommended that the tristimulus values of object colours be expressed on a scale having a tristimulus value of Y = 100 ... for a perfect reflecting diffuser ... under identical conditions of illumination and observation."[1]

Unidimensional scaling. A general technique of experimentation. In this research, to create a visual scale, a scaling method called Partition Judgments was used. This technique is only one of eight scaling methods [18,19] that integrate the general unidimensional scaling experimentation.

Uniform colour space. "Colour space in which the distance between any two colour points is intended to represent a measure of the perceived difference between the corresponding colours."[1]

Weighting functions. Variables used in the improved color difference equation shown in Chapter 2, and stated as $S_L = 1$, $S_C = 1 + 0.045C^*$, and $S_H = 1 + 0.015C^*$.

Endnotes for Glossary

1. Commission Internationale De L'Eclairage (CIE). **International Lighting Vocabulary**. 3rd Edition, Paris, France. 1970. Sections 45-15 – Colorimetry: Fundamental concepts and Quantities, 52-77 and 45-25 – Eye and Vision. Colour rendering, 102-129

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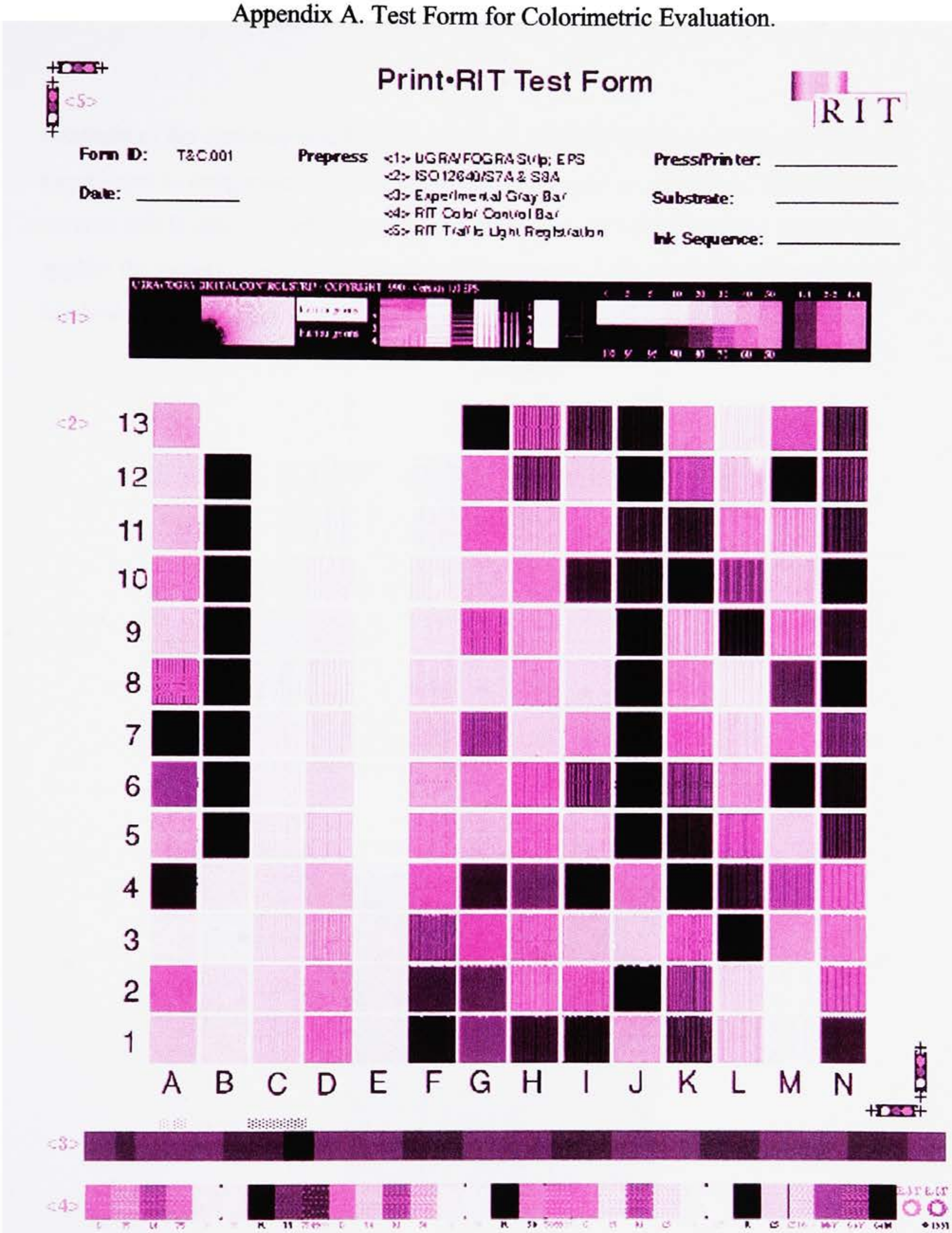
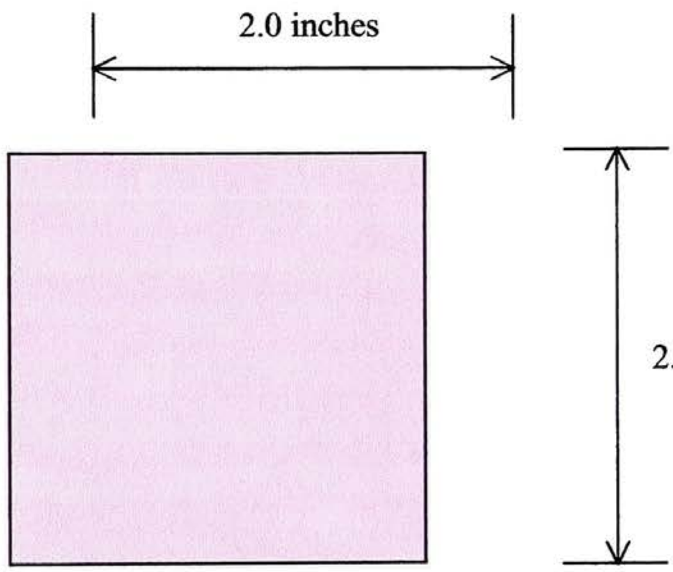
Appendices

Appendix A. Test Form for Colorimetric Evaluation.

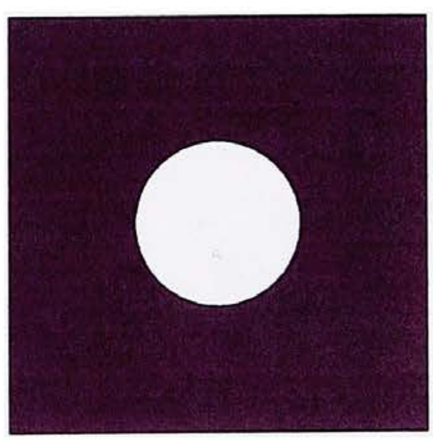


Appendix B. Test Form for Visual Assessment.

Example of the Anverse and Reverse sides of Gray Patches used in the psychometric experiment to determine a Visual Scale. Measurements are in inches. The circle in the reverse side is used to identify each patch from the point of view of the person who applies the experiment to each observer. The material is described in Chapter 5: Methodology

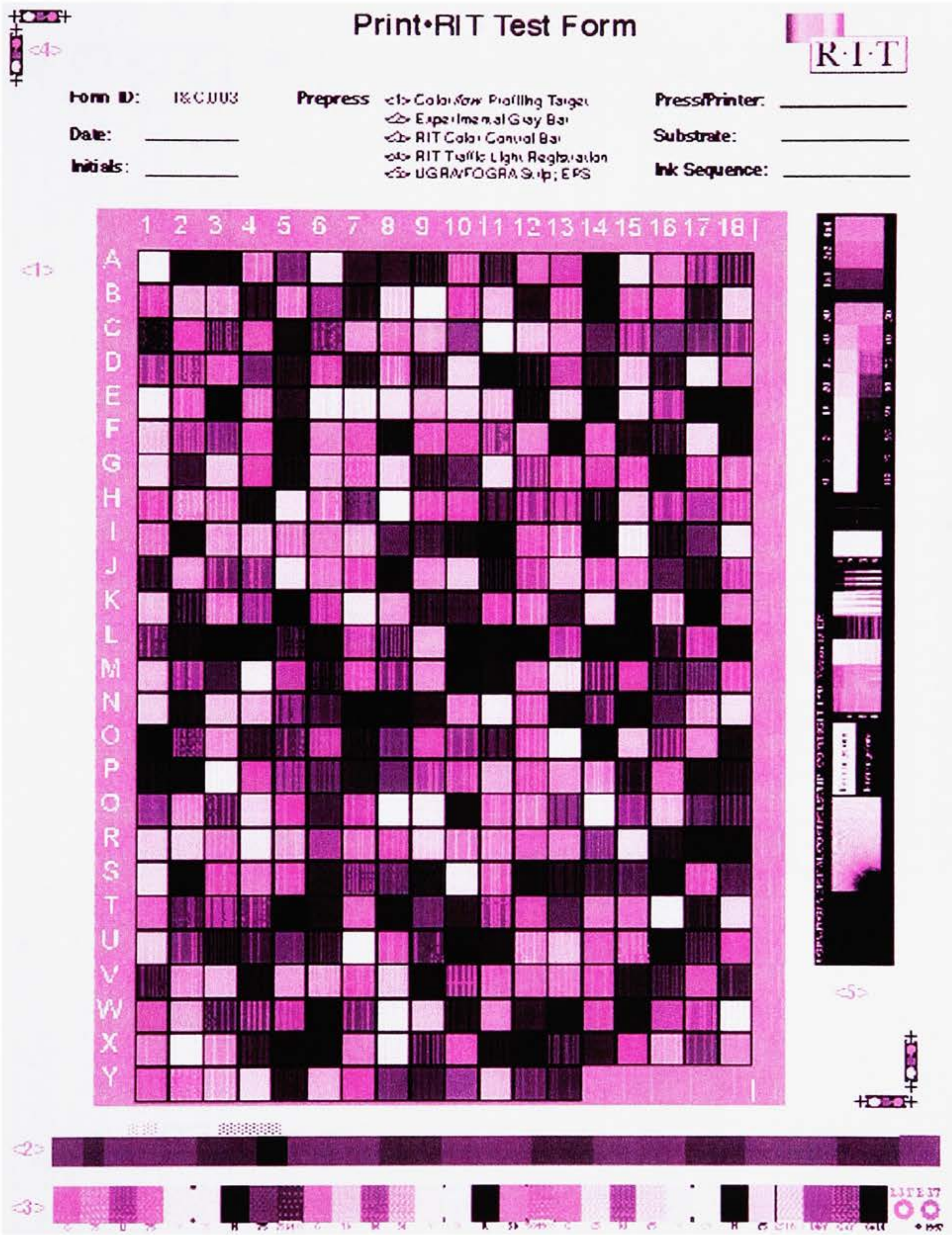


Anverse side



Reverse side

Appendix C. Test Form for Profile Generation.



Appendix D01. Colorimetric Data Sheet for Sample No. 01 (Delta L* = -50).

ID	L*	a*	b*
1	31.4	-27.7	-30.2
2	24.2	13.9	-3.1
3	78.1	-0.1	76.5
4	25.6	13.9	-41.3
5	32.5	-28.9	6.2
6	28.3	15.9	4.9
7	6.4	-0.7	-4.9
8	33.6	9.4	-31.7
9	38.4	-28.1	11.0
10	33.9	24.0	12.7
11	42.4	5.0	-19.0
12	43.1	18.0	14.4
13	29.3	2.7	0.6
14	50.5	-16.4	5.2
15	56.1	3.4	-12.1
16	61.4	-8.0	1.9
17	59.9	11.1	5.8
18	5.9	-0.7	-4.8
19	4.7	-0.2	-3.1
20	10.0	-1.9	-5.2
21	5.4	-0.5	-4.2
22	5.0	-0.3	-3.4
23	4.8	-0.2	-3.3
24	4.3	-0.1	-2.7
25	5.5	-0.6	-4.0
26	76.6	1.7	-3.3
27	33.6	-28.2	-29.8
28	36.1	-28.5	-28.0
29	39.8	-24.7	-26.1
30	43.8	-20.5	-23.3
31	47.1	-18.6	-20.8
32	51.3	-14.0	-18.1
33	56.3	-10.5	-15.2
34	58.6	-8.6	-13.5
35	61.6	-7.6	-11.2
36	64.7	-5.6	-9.0
37	68.1	-2.0	-8.3
38	70.0	-0.7	-7.5
39	73.4	0.6	-5.6
40	24.6	14.8	-3.7
41	26.5	18.4	-3.7
42	29.2	25.7	-4.9
43	31.8	26.5	-4.3
44	35.7	24.0	-5.1
45	41.7	19.8	-5.2
46	48.1	15.5	-5.3
47	51.8	13.5	-5.1
48	56.1	11.5	-5.5
49	61.0	9.9	-4.9
50	66.4	7.5	-4.4

ID	L*	a*	b*
51	69.1	5.6	-4.3
52	73.4	3.4	-5.0
53	76.6	-0.2	68.6
54	75.9	-0.9	59.4
55	75.8	-0.2	48.6
56	75.6	-0.3	39.4
57	75.8	-1.2	32.5
58	76.3	0.2	25.4
59	76.2	-0.2	17.2
60	76.7	0.5	13.2
61	77.3	0.5	11.1
62	77.1	0.5	7.3
63	76.8	1.4	2.0
64	76.9	1.6	-0.4
65	76.5	2.1	-2.1
66	7.0	-1.0	-5.0
67	9.5	-1.7	-5.4
68	12.3	-1.1	-4.9
69	16.4	-0.4	-3.6
70	23.3	-0.5	-2.7
71	34.5	0.1	-2.6
72	42.9	0.0	-3.5
73	47.9	0.0	-3.5
74	53.3	0.4	-4.4
75	58.5	0.7	-3.7
76	64.8	1.5	-3.8
77	68.4	1.3	-4.2
78	72.8	1.8	-4.6
79	21.6	12.4	-10.5
80	14.7	0.7	-5.2
81	23.4	9.2	-1.2
82	14.7	0.0	-4.4
83	43.5	16.3	33.6
84	39.5	1.4	23.5
85	12.6	-1.2	-4.9
86	54.6	-20.9	44.1
87	18.4	-9.4	-2.9
88	22.3	-17.8	-8.5
89	15.8	-9.4	-8.4
90	27.8	-16.2	-32.1
91	21.3	2.4	-18.6
92	20.9	9.3	-12.7
93	19.2	4.0	-3.8
94	18.0	3.1	-3.3
95	19.4	3.2	-2.3
96	23.3	6.4	0.7
97	28.3	11.1	6.0
98	52.6	1.1	28.1
99	36.8	-17.8	16.0
100	30.7	-15.2	4.3

ID	L*	a*	b*
101	13.5	-6.7	-4.8
102	28.3	-14.0	-13.6
103	25.5	-7.7	-25.4
104	28.2	7.4	-18.2
105	8.9	-1.2	-6.1
106	8.7	-1.3	-5.7
107	32.3	9.7	-2.5
108	8.3	-1.3	-5.5
109	37.6	9.0	7.8
110	28.3	0.7	5.5
111	39.3	0.7	13.8
112	54.2	1.5	9.1
113	47.6	1.9	-1.5
114	10.2	-3.0	-5.6
115	17.6	-4.9	-3.0
116	38.3	-7.3	2.2
117	8.3	-1.9	-5.7
118	32.8	4.0	-5.9
119	16.9	-0.5	-11.0
120	37.9	-4.2	-7.0
121	13.5	-3.1	-6.5
122	4.7	-0.2	-3.2
123	5.0	-0.3	-3.5
124	5.5	-0.5	-4.1
125	4.8	-0.3	-3.3
126	5.3	-0.5	-4.2
127	6.1	-0.8	-4.8
128	7.3	-1.0	-5.3
129	4.9	-0.4	-3.5
130	5.9	-0.6	-4.5
131	7.5	-1.2	-5.4
132	9.0	-1.6	-5.6
133	11.2	-1.5	-5.5
134	5.3	-0.4	-4.0
135	7.1	-1.1	-5.3
136	10.0	-1.6	-6.1
137	12.3	-1.8	-5.5
138	18.9	-2.0	-4.3
139	26.0	-1.7	-3.3
140	5.3	-0.5	-4.0
141	8.7	-1.4	-5.6
142	12.8	-1.3	-5.3
143	20.7	-0.7	-4.0
144	36.4	-1.8	-4.0
145	43.7	-2.2	-4.8
146	5.4	-0.5	-4.0
147	9.2	-1.4	-5.6
148	14.4	-0.8	-5.0
149	27.6	-0.4	-2.8
150	43.5	-1.1	-4.2

ID	L*	a*	b*
151	53.8	-0.4	-5.0
152	7.5	-1.3	-5.5
153	9.9	-1.9	-5.7
154	14.5	-1.7	-5.1
155	32.7	-1.5	-4.9
156	52.3	-0.4	-4.8
157	62.9	0.5	-4.5
158	69.2	0.6	-3.9
159	26.8	-20.7	-24.5
160	20.1	6.2	-4.4
161	58.3	-1.3	54.7
162	22.4	13.5	-35.3
163	24.8	-16.4	0.0
164	22.2	6.3	-0.4
165	34.7	3.8	-16.4
166	38.2	-13.3	2.4
167	33.6	12.4	7.9
168	19.5	9.5	-27.8
169	18.8	-9.5	-3.0
170	15.5	0.3	-4.3
171	28.6	2.3	-13.7
172	18.4	-4.7	-3.0
173	19.1	1.9	-2.9
174	15.2	-6.6	-10.9
175	8.5	-1.2	-6.1
176	32.4	-2.4	12.5
177	10.4	-1.5	-8.1
178	9.3	-2.9	-5.4
179	8.2	-1.3	-5.8
180	16.5	-1.8	-9.6
181	9.1	-2.1	-5.7
182	10.9	-1.7	-5.7

Appendix D02. Colorimetric Data Sheet for Sample No. 02 (Delta L* = -45).

ID	L*	a*	b*
1	32.5	-31.7	-28.8
2	25.8	19.5	0.0
3	78.1	-0.8	79.0
4	24.3	13.5	-40.9
5	34.4	-32.8	10.8
6	29.5	20.1	11.0
7	6.9	-1.1	-3.7
8	34.2	8.7	-28.8
9	40.1	-28.6	13.7
10	35.0	25.3	18.0
11	43.6	2.8	-17.1
12	44.9	17.0	17.0
13	30.6	1.8	3.4
14	51.8	-18.6	7.5
15	57.5	2.0	-11.1
16	62.6	-9.0	1.9
17	61.0	9.6	7.9
18	5.7	-0.8	-3.4
19	4.1	-0.3	-2.0
20	8.9	-1.7	-3.4
21	4.8	-0.5	-2.7
22	4.6	-0.4	-2.2
23	4.2	-0.3	-2.0
24	3.8	-0.1	-1.6
25	5.3	-0.6	-2.7
26	77.6	1.6	-3.0
27	34.9	-31.3	-28.3
28	37.9	-31.0	-26.1
29	41.1	-28.6	-24.6
30	44.7	-24.5	-22.5
31	49.6	-19.6	-19.2
32	52.9	-16.2	-16.9
33	57.8	-11.8	-13.4
34	60.8	-10.4	-10.7
35	63.4	-7.4	-9.7
36	66.3	-5.3	-8.8
37	69.2	-2.8	-7.4
38	71.2	-1.4	-6.2
39	74.4	0.0	-3.9
40	26.0	20.9	-1.0
41	27.3	23.9	-1.4
42	29.1	27.8	-2.2
43	32.2	26.7	-2.8
44	38.5	23.0	-2.6
45	43.1	19.1	-3.7
46	50.4	14.9	-4.0
47	53.7	13.0	-4.4
48	58.7	10.2	-3.5
49	62.8	8.8	-4.5
50	67.6	6.1	-2.8

ID	L*	a*	b*
51	70.6	5.0	-4.1
52	74.3	2.8	-3.3
53	76.4	-0.7	69.4
54	76.4	-0.8	60.4
55	76.0	-1.1	50.4
56	75.8	-1.5	42.4
57	76.1	-1.3	32.5
58	76.5	-0.9	27.0
59	76.7	-0.1	17.6
60	77.6	-0.1	14.4
61	78.0	0.1	11.9
62	77.9	0.6	7.6
63	77.8	1.0	2.8
64	77.5	1.1	0.9
65	77.2	1.1	-0.5
66	7.8	-1.4	-3.7
67	11.8	-0.9	-2.6
68	15.1	-0.7	-1.7
69	18.0	-0.8	-1.1
70	26.8	-0.8	-0.1
71	36.2	-1.2	-1.2
72	45.3	-1.3	-1.9
73	49.9	-0.5	-1.2
74	55.8	0.0	-2.7
75	60.3	-0.6	-3.2
76	66.4	0.1	-2.4
77	69.4	0.5	-2.6
78	73.6	1.9	-4.1
79	22.3	16.0	-9.6
80	16.8	2.9	-2.2
81	24.7	13.9	2.8
82	16.6	1.8	-0.4
83	45.0	16.6	39.8
84	39.5	1.1	27.5
85	14.8	0.1	-1.2
86	55.2	-22.1	46.6
87	21.6	-12.8	1.6
88	25.3	-24.0	-7.3
89	18.1	-12.3	-7.1
90	28.4	-19.0	-30.1
91	20.7	2.4	-17.5
92	20.7	11.3	-11.8
93	22.2	9.5	-0.3
94	21.4	6.7	1.1
95	20.6	6.6	1.4
96	27.2	11.2	7.1
97	30.4	15.2	12.8
98	53.2	0.1	29.4
99	37.5	-19.2	19.2
100	33.4	-18.2	8.5

ID	L*	a*	b*
101	17.0	-12.3	-1.9
102	31.2	-16.9	-11.5
103	25.8	-9.8	-23.5
104	28.7	5.6	-17.0
105	9.7	-1.5	-4.4
106	11.8	-1.1	-3.2
107	34.2	9.2	0.6
108	9.0	-1.7	-3.7
109	39.0	9.1	9.8
110	28.5	0.6	10.1
111	40.2	-0.1	16.5
112	55.6	0.9	10.6
113	50.3	1.0	1.2
114	10.6	-4.1	-3.1
115	21.5	-6.3	2.2
116	40.2	-7.3	3.7
117	8.4	-2.5	-3.9
118	34.6	2.9	-4.5
119	16.8	-1.1	-8.7
120	39.8	-5.8	-5.1
121	15.7	-4.0	-3.2
122	4.1	-0.1	-1.9
123	4.6	-0.2	-2.0
124	5.3	-0.4	-2.6
125	4.3	-0.2	-1.8
126	5.2	-0.5	-2.7
127	6.3	-0.9	-3.1
128	8.2	-1.4	-3.8
129	4.4	-0.3	-2.1
130	6.0	-0.8	-3.2
131	8.0	-1.2	-3.5
132	10.3	-1.6	-3.3
133	12.8	-1.9	-2.7
134	4.6	-0.3	-2.3
135	7.2	-1.2	-3.7
136	10.7	-1.6	-3.2
137	13.9	-1.9	-2.7
138	21.6	-2.2	-1.4
139	29.4	-2.0	-1.0
140	4.9	-0.4	-2.6
141	9.7	-1.5	-3.5
142	14.5	-0.8	-1.8
143	22.9	-1.7	-1.2
144	38.9	-2.5	-2.3
145	46.0	-2.6	-2.8
146	4.9	-0.5	-2.6
147	10.3	-1.7	-3.5
148	16.3	-1.1	-1.9
149	29.8	-1.6	-1.0
150	46.0	-1.8	-2.9

ID	L*	a*	b*
151	55.5	-1.0	-4.0
152	7.8	-1.5	-3.7
153	11.5	-1.8	-3.2
154	16.9	-2.3	-1.6
155	35.1	-3.2	-1.1
156	54.4	-2.4	-3.5
157	65.1	-0.6	-3.1
158	70.7	0.3	-2.2
159	27.6	-24.7	-23.2
160	21.6	10.1	-1.8
161	58.8	-2.0	58.0
162	21.7	12.3	-33.8
163	27.5	-20.7	3.9
164	23.9	10.4	4.8
165	35.9	3.1	-15.0
166	39.7	-14.9	4.7
167	35.7	13.5	12.9
168	18.5	8.9	-25.6
169	21.0	-13.6	1.1
170	17.0	1.8	-0.5
171	29.4	1.8	-12.0
172	22.0	-7.4	1.9
173	21.9	4.3	2.0
174	15.5	-8.1	-9.3
175	8.8	-1.5	-4.1
176	32.4	-2.8	16.0
177	9.1	-1.6	-5.7
178	9.6	-4.0	-3.1
179	8.3	-1.5	-3.9
180	16.9	-2.2	-6.8
181	9.9	-2.9	-3.3
182	12.4	-0.3	-2.5

Appendix D03. Colorimetric Data Sheet for Sample No. 03 (Delta L* = -40).

ID	L*	a*	b*
1	34.1	-34.4	-29.1
2	27.0	25.4	-0.4
3	78.4	-1.1	78.1
4	24.8	13.2	-40.3
5	35.9	-36.6	12.4
6	30.7	24.8	12.6
7	8.6	-1.5	-3.5
8	34.3	8.9	-30.8
9	40.8	-30.6	13.4
10	37.4	28.6	20.1
11	44.6	3.9	-17.8
12	46.5	17.8	16.4
13	33.7	2.0	3.0
14	53.9	-18.4	7.4
15	58.8	2.7	-11.0
16	64.0	-9.1	1.6
17	62.1	10.4	8.1
18	5.7	-0.9	-3.3
19	4.4	-0.3	-2.2
20	9.5	-1.9	-3.3
21	4.7	-0.4	-2.5
22	4.7	-0.4	-2.6
23	4.6	-0.3	-2.2
24	3.9	-0.1	-1.7
25	6.0	-0.9	-3.2
26	78.2	1.3	-3.5
27	36.4	-33.6	-28.5
28	39.3	-31.5	-27.7
29	43.1	-27.8	-26.1
30	47.0	-23.8	-23.8
31	51.3	-19.4	-20.7
32	55.0	-15.4	-17.7
33	59.4	-11.5	-14.4
34	61.7	-9.8	-12.7
35	64.8	-7.8	-11.2
36	67.5	-5.3	-9.7
37	70.6	-2.8	-7.5
38	72.4	-1.6	-6.1
39	75.5	0.0	-4.0
40	26.9	26.4	-1.6
41	27.8	28.7	-2.0
42	30.5	30.4	-3.3
43	34.2	28.5	-2.8
44	40.4	24.0	-3.6
45	45.8	19.8	-4.3
46	52.2	15.6	-4.5
47	55.9	12.8	-4.1
48	60.1	12.0	-4.3
49	64.4	9.3	-4.4
50	69.0	6.0	-3.8

ID	L*	a*	b*
51	71.8	5.2	-4.7
52	75.2	3.2	-2.8
53	77.1	-0.5	69.5
54	76.3	-0.8	59.4
55	76.5	-0.8	49.8
56	76.1	-0.8	42.4
57	76.4	-1.7	32.8
58	76.9	-0.9	26.4
59	77.5	-0.5	17.5
60	77.7	0.0	14.3
61	78.5	0.4	11.6
62	78.4	0.7	6.7
63	78.3	1.1	3.1
64	77.9	1.2	0.6
65	78.2	1.0	-1.0
66	10.1	-1.2	-3.0
67	14.5	-0.4	-1.6
68	17.9	-0.8	-0.9
69	21.8	-1.1	-0.5
70	30.3	-1.1	-0.6
71	38.8	-1.3	-0.9
72	47.1	-1.4	-2.4
73	51.6	-1.3	-2.3
74	56.9	-0.4	-3.2
75	62.7	0.5	-3.5
76	67.6	0.7	-3.9
77	70.5	0.9	-2.8
78	74.9	1.2	-3.3
79	23.5	20.4	-10.8
80	19.9	7.6	-1.1
81	27.9	20.6	5.3
82	19.5	4.9	1.4
83	46.1	18.3	41.8
84	40.6	1.8	28.8
85	17.0	0.7	-0.7
86	55.9	-22.8	47.7
87	24.9	-16.2	3.4
88	28.8	-30.6	-9.4
89	20.9	-16.0	-9.8
90	29.3	-19.4	-31.3
91	21.4	3.5	-19.1
92	21.6	13.8	-12.7
93	26.2	15.5	0.3
94	26.0	13.0	3.9
95	23.7	11.3	3.6
96	30.8	16.6	10.6
97	32.9	18.3	16.5
98	53.9	-0.6	29.6
99	37.9	-20.8	20.6
100	35.5	-20.0	9.7

ID	L*	a*	b*
101	22.9	-16.9	-0.6
102	32.3	-18.0	-13.0
103	26.6	-9.6	-25.0
104	29.8	5.9	-17.2
105	12.6	0.0	-3.5
106	17.0	2.2	-1.2
107	36.8	9.3	0.3
108	11.6	-0.8	-3.2
109	40.3	8.2	9.6
110	29.9	0.4	11.3
111	40.9	-0.3	16.7
112	56.0	0.8	10.7
113	51.6	1.0	0.2
114	14.3	-5.3	-1.9
115	25.5	-9.0	4.4
116	42.4	-7.4	3.6
117	10.6	-4.2	-4.1
118	36.6	3.4	-5.9
119	17.3	0.0	-9.0
120	42.0	-6.3	-4.9
121	20.3	-6.4	-3.7
122	4.2	-0.1	-2.0
123	4.9	-0.3	-2.4
124	5.6	-0.6	-2.9
125	4.2	-0.1	-2.1
126	5.3	-0.6	-2.7
127	7.6	-1.0	-3.6
128	9.5	-1.8	-3.5
129	4.6	-0.2	-2.5
130	6.7	-1.0	-3.7
131	9.6	-1.7	-3.3
132	12.9	-1.5	-2.3
133	15.7	-2.2	-1.8
134	5.1	-0.3	-2.7
135	9.0	-1.6	-3.6
136	13.8	-1.2	-2.2
137	17.3	-2.0	-1.6
138	26.2	-2.3	-1.2
139	32.0	-3.3	-2.0
140	5.7	-0.6	-2.9
141	12.5	-0.7	-2.5
142	17.8	-0.9	-1.3
143	27.3	-1.5	-0.9
144	41.0	-2.8	-2.1
145	48.4	-3.0	-2.2
146	5.9	-0.7	-3.1
147	13.3	-0.5	-2.2
148	19.7	-1.1	-0.6
149	33.4	-1.8	-0.6
150	48.4	-2.0	-2.5

ID	L*	a*	b*
151	57.4	-1.4	-3.8
152	9.5	-1.9	-3.5
153	14.1	-2.2	-2.2
154	20.5	-2.9	-1.6
155	37.7	-3.0	-2.7
156	56.1	-1.9	-4.3
157	66.6	-0.1	-3.3
158	72.0	0.9	-4.1
159	28.8	-25.5	-25.0
160	23.6	14.5	-2.5
161	59.7	-1.7	59.5
162	21.8	13.3	-34.7
163	31.2	-26.5	6.4
164	25.9	13.9	6.0
165	37.1	3.2	-15.8
166	41.7	-15.0	4.4
167	36.6	13.2	13.0
168	18.7	9.3	-25.9
169	24.3	-16.6	2.9
170	19.6	4.9	1.2
171	30.9	2.0	-11.5
172	26.6	-9.9	3.3
173	25.5	6.7	4.3
174	16.8	-9.8	-10.3
175	10.5	-1.0	-3.6
176	32.9	-2.6	17.3
177	9.6	-1.7	-6.1
178	11.9	-5.8	-2.6
179	9.9	-1.2	-3.3
180	17.8	-1.7	-6.4
181	11.9	-3.9	-2.1
182	15.0	0.3	-1.3

Appendix D04. Colorimetric Data Sheet for Sample No. 04 (Delta L* = -35).

ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*
1	36.2	-36.0	-31.6	51	73.0	5.2	-3.8	101	37.3	-21.4	9.1	151	59.2	-0.9	-3.4
2	27.4	29.1	-0.5	52	76.4	2.8	-2.8	102	26.6	-23.8	-0.9	152	11.3	-2.8	-3.3
3	78.9	-1.0	79.7	53	77.5	-0.6	70.0	103	34.7	-18.7	-13.6	153	16.6	-3.3	-2.3
4	24.8	13.4	-41.3	54	76.7	-1.5	60.5	104	26.8	-10.6	-26.0	154	25.5	-3.3	-1.3
5	36.7	-40.7	13.6	55	76.2	-0.8	50.8	105	30.6	6.1	-18.2	155	40.2	-4.2	-2.3
6	32.1	28.1	14.9	56	76.4	-1.0	42.7	106	15.3	1.3	-3.0	156	57.9	-1.8	-4.0
7	11.1	-1.0	-2.7	57	76.8	-1.5	34.5	107	21.5	6.0	-0.3	157	68.1	0.1	-3.9
8	35.0	9.5	-30.6	58	77.3	-0.9	26.7	108	38.1	9.4	-0.5	158	73.4	0.6	-4.3
9	42.8	-30.0	13.0	59	77.9	-0.5	17.3	109	14.6	0.1	-1.7	159	29.8	-27.8	-25.3
10	38.4	31.0	22.1	60	78.3	0.0	14.6	110	41.7	8.9	10.0	160	26.0	20.5	-1.6
11	45.8	4.5	-19.8	61	79.3	0.4	11.0	111	31.2	0.8	13.4	161	60.0	-2.6	59.8
12	48.8	18.7	17.4	62	78.9	0.8	6.7	112	41.7	-0.5	17.5	162	21.8	13.0	-34.4
13	36.3	1.9	3.1	63	78.8	0.9	2.7	113	57.1	1.0	10.7	163	33.8	-30.9	8.7
14	55.3	-19.1	6.9	64	78.8	1.1	1.4	114	53.9	1.6	0.3	164	29.0	18.4	9.3
15	59.9	2.0	-10.1	65	78.9	1.6	-1.9	115	17.0	-8.0	-0.1	165	38.6	3.3	-15.4
16	65.2	-8.6	0.8	66	13.2	-0.9	-1.8	116	29.2	-11.4	5.3	166	42.8	-15.1	5.2
17	63.5	10.7	8.5	67	16.5	-1.0	-1.4	117	43.9	-8.5	4.0	167	38.4	14.9	14.5
18	6.1	-1.2	-4.0	68	21.0	-1.0	-0.6	118	14.4	-7.1	-4.0	168	18.7	9.4	-26.0
19	4.7	-0.2	-2.5	69	26.0	-1.3	-0.2	119	39.0	3.7	-5.5	169	27.6	-21.0	4.2
20	10.4	-1.8	-2.5	70	33.1	-1.9	-0.1	120	18.2	0.3	-9.2	170	22.4	8.1	3.1
21	5.0	-0.5	-2.8	71	41.3	-1.7	-0.4	121	44.3	-6.1	-5.0	171	31.7	1.8	-13.0
22	5.0	-0.5	-2.7	72	49.6	-1.1	-1.3	122	25.0	-7.9	-4.4	172	30.5	-11.4	3.7
23	4.5	-0.3	-2.4	73	54.4	-0.7	-2.9	123	4.2	-0.2	-2.0	173	29.1	8.9	6.8
24	3.9	-0.1	-1.9	74	58.8	-0.1	-2.9	124	5.1	-0.4	-2.4	174	17.8	-10.9	-11.4
25	7.1	-1.2	-3.7	75	63.6	-0.1	-3.0	125	6.6	-0.9	-3.3	175	12.3	0.1	-3.1
26	79.1	1.7	-3.4	76	69.0	0.9	-3.2	126	4.5	-0.2	-2.1	176	33.7	-2.7	17.9
27	38.3	-33.9	-31.0	77	71.7	1.0	-3.4	127	6.4	-1.0	-3.4	177	10.2	-1.6	-6.4
28	41.2	-31.8	-28.9	78	75.6	1.3	-3.0	128	9.0	-1.5	-3.2	178	14.2	-7.1	-2.0
29	44.7	-28.7	-26.2	79	24.1	23.7	-12.5	129	12.3	-1.3	-2.5	179	11.8	-0.8	-3.1
30	48.7	-25.1	-23.1	80	22.4	11.4	-1.3	130	4.7	-0.4	-2.5	180	19.3	0.0	-7.1
31	52.6	-20.6	-20.7	81	29.1	25.2	5.9	131	8.4	-1.7	-3.8	181	15.2	-5.6	-0.7
32	56.7	-17.1	-16.9	82	22.9	9.5	3.5	132	12.2	-1.7	-2.5	182	17.8	1.9	-0.2
33	61.1	-11.8	-14.0	83	47.3	19.7	43.7	133	15.3	-2.3	-2.4				
34	63.2	-10.1	-12.9	84	41.3	1.5	30.6	134	18.8	-3.3	-1.8				
35	66.1	-7.3	-11.4	85	20.5	1.0	0.5	135	5.5	-0.8	-3.0				
36	68.9	-4.4	-9.5	86	56.6	-22.0	48.2	136	11.3	-1.6	-2.8				
37	71.7	-2.5	-7.1	87	28.2	-18.9	5.0	137	16.0	-1.8	-1.9				
38	73.5	-1.8	-5.9	88	29.8	-33.7	-10.1	138	21.3	-2.6	-1.5				
39	76.7	0.5	-4.8	89	23.7	-18.9	-10.9	139	29.6	-3.2	-1.3				
40	27.6	30.9	-2.6	90	29.7	-20.7	-31.9	140	34.8	-2.8	-2.0				
41	29.0	33.7	-2.3	91	21.5	3.5	-19.7	141	6.4	-0.8	-3.3				
42	32.2	32.7	-3.1	92	22.2	15.8	-14.8	142	15.5	-0.9	-1.6				
43	36.5	29.6	-2.9	93	28.5	19.7	0.0	143	20.6	-2.0	-1.8				
44	42.4	25.9	-3.9	94	29.2	17.8	5.2	144	30.4	-2.6	-1.5				
45	48.3	20.5	-4.6	95	26.8	16.8	5.5	145	43.0	-3.2	-2.7				
46	54.4	16.0	-3.8	96	33.5	19.5	13.9	146	50.8	-2.4	-3.1				
47	57.7	14.1	-3.6	97	34.3	19.7	18.7	147	6.8	-1.3	-3.6				
48	62.1	12.1	-4.9	98	54.9	-0.2	30.3	148	16.2	-0.7	-1.5				
49	66.0	9.3	-4.2	99	38.9	-22.0	21.9	149	23.7	-2.0	-0.5				
50	70.6	6.7	-5.0	100	37.3	-21.4	9.1	150	35.6	-1.8	-1.5				

Appendix D05. Colorimetric Data Sheet for Sample No. 05 (Delta L* = -30).

ID	L*	a*	b*
1	38.1	-37.2	-32.9
2	28.0	33.8	-2.1
3	78.6	-0.8	78.5
4	25.0	13.7	-41.9
5	38.7	-42.8	15.0
6	33.5	33.3	17.5
7	13.1	-0.7	-2.1
8	35.4	9.2	-31.6
9	43.5	-32.5	12.9
10	39.9	32.9	23.5
11	47.1	4.8	-19.7
12	51.1	20.0	16.2
13	38.5	1.7	3.0
14	57.0	-18.6	6.5
15	60.8	2.7	-11.9
16	66.6	-9.0	1.5
17	64.9	10.8	7.0
18	7.0	-1.2	-4.3
19	4.9	-0.3	-2.5
20	10.7	-1.7	-3.0
21	4.8	-0.4	-2.8
22	5.5	-0.6	-2.7
23	4.8	-0.3	-2.5
24	4.1	-0.1	-1.9
25	8.8	-1.5	-3.5
26	79.7	2.1	-3.9
27	41.1	-35.5	-31.4
28	43.8	-33.6	-30.0
29	47.3	-29.7	-27.9
30	50.6	-25.6	-24.7
31	54.7	-20.1	-20.6
32	57.9	-16.7	-18.2
33	62.3	-11.8	-15.0
34	64.6	-10.3	-13.2
35	67.0	-7.4	-11.4
36	70.3	-4.7	-9.0
37	72.8	-2.4	-7.5
38	74.4	-1.3	-7.3
39	77.2	0.4	-5.6
40	28.8	36.3	-1.9
41	30.3	36.9	-2.4
42	34.2	35.5	-4.1
43	38.8	31.2	-4.7
44	45.5	25.8	-4.8
45	51.0	20.8	-4.9
46	57.1	16.2	-4.6
47	60.1	14.5	-5.3
48	63.3	12.3	-5.1
49	67.3	9.3	-5.1
50	71.8	7.1	-5.0

ID	L*	a*	b*
51	73.9	5.6	-4.2
52	77.3	3.4	-4.6
53	78.0	-0.6	69.7
54	76.4	-1.5	60.5
55	77.1	-0.8	50.6
56	76.8	-0.7	41.6
57	77.2	-1.2	32.4
58	77.7	-1.3	25.9
59	78.3	-0.5	16.7
60	78.5	-0.1	14.6
61	79.3	0.6	11.1
62	79.2	0.7	6.3
63	78.9	1.2	2.4
64	79.1	1.1	0.9
65	79.2	2.0	-1.9
66	15.4	-0.1	-1.4
67	19.4	-0.6	-0.8
68	24.7	-0.7	-0.1
69	29.4	-1.2	-1.1
70	36.3	-0.3	-1.5
71	42.7	-1.4	-2.3
72	51.9	-1.4	-2.6
73	56.0	-0.2	-3.6
74	60.2	-0.1	-3.6
75	64.9	0.6	-3.2
76	69.9	0.6	-2.9
77	72.9	1.1	-4.6
78	76.3	1.1	-3.5
79	24.6	27.0	-13.8
80	24.2	15.7	-1.6
81	29.7	30.8	6.4
82	26.1	14.1	6.0
83	49.1	20.9	45.7
84	41.8	1.2	31.1
85	23.3	1.4	0.7
86	57.0	-22.5	48.7
87	31.6	-23.9	6.5
88	31.2	-37.1	-11.8
89	26.7	-22.1	-13.1
90	30.9	-20.6	-34.3
91	22.4	4.1	-20.7
92	22.7	18.2	-15.3
93	29.5	23.3	-1.3
94	31.5	22.2	6.5
95	29.4	22.6	7.6
96	35.7	22.9	15.7
97	35.4	21.8	21.2
98	55.7	0.3	29.5
99	39.8	-22.3	23.8
100	38.6	-21.3	9.4

ID	L*	a*	b*
101	30.1	-32.2	-1.2
102	36.0	-19.2	-15.6
103	27.8	-11.0	-26.9
104	31.5	6.6	-19.8
105	18.3	4.5	-1.9
106	25.2	10.1	0.5
107	40.4	9.7	-0.6
108	17.7	2.4	0.0
109	43.9	9.8	8.3
110	32.2	1.0	13.9
111	42.3	0.5	16.8
112	57.8	1.1	10.1
113	55.3	1.6	-0.8
114	20.2	-10.3	0.2
115	32.3	-12.1	5.6
116	46.2	-7.4	3.2
117	17.3	-9.1	-5.0
118	40.9	3.1	-6.8
119	19.1	0.2	-9.6
120	45.6	-7.1	-6.2
121	28.9	-9.2	-5.5
122	4.4	-0.1	-2.2
123	5.3	-0.5	-2.8
124	7.1	-1.0	-3.8
125	4.7	-0.4	-2.5
126	7.1	-1.3	-3.7
127	10.4	-1.8	-3.7
128	13.8	-2.0	-2.3
129	5.5	-0.5	-3.1
130	9.7	-1.8	-3.5
131	13.8	-2.3	-2.4
132	18.2	-3.2	-1.4
133	22.7	-3.9	-1.6
134	6.3	-0.9	-3.4
135	13.1	-1.7	-2.5
136	18.5	-2.2	-1.5
137	25.9	-2.2	-1.4
138	32.5	-3.1	-1.8
139	37.7	-3.2	-2.7
140	7.5	-1.1	-3.5
141	16.9	-0.9	-1.7
142	25.0	-1.5	-1.1
143	33.5	-2.4	-2.0
144	45.5	-2.5	-2.9
145	52.6	-2.2	-3.6
146	8.0	-1.5	-3.6
147	18.1	-0.8	-1.7
148	27.9	-1.5	-0.8
149	38.0	-2.1	-2.6
150	52.6	-1.1	-3.6

ID	L*	a*	b*
151	60.7	-0.6	-4.6
152	12.5	-3.9	-3.3
153	19.8	-4.2	-2.7
154	28.9	-3.6	-1.8
155	42.3	-3.8	-3.7
156	59.1	-1.6	-4.6
157	69.2	0.0	-3.8
158	73.8	1.1	-4.6
159	30.9	-29.8	-26.6
160	26.8	24.9	-2.9
161	60.7	-1.8	60.1
162	21.9	13.7	-35.5
163	35.0	-33.9	10.5
164	30.6	23.1	11.4
165	39.5	4.2	-15.7
166	44.3	-15.8	5.5
167	39.4	15.0	14.5
168	18.6	9.9	-26.9
169	30.1	-25.1	5.9
170	24.8	11.1	5.2
171	32.6	1.9	-13.6
172	33.8	-12.5	4.6
173	32.7	12.1	10.0
174	20.2	-12.9	-12.9
175	14.5	1.1	-2.6
176	34.0	-2.3	18.4
177	10.1	-1.4	-6.5
178	16.6	-9.3	-0.8
179	14.2	0.6	-2.0
180	21.3	-0.4	-7.9
181	18.9	-6.6	0.2
182	20.9	4.1	1.2

Appendix D06. Colorimetric Data Sheet for Sample No. 06 (Delta L* = -25).

ID	L*	a*	b*
1	40.4	-37.1	-36.0
2	29.3	38.5	-2.8
3	78.7	-0.9	77.4
4	25.0	14.3	-42.6
5	39.6	-47.3	15.5
6	35.1	37.5	18.7
7	15.0	0.0	-1.7
8	36.1	9.0	-31.9
9	45.8	-32.3	12.6
10	42.3	35.2	25.6
11	48.4	4.7	-19.8
12	53.1	20.8	17.0
13	40.5	2.1	2.4
14	58.5	-19.0	5.0
15	62.4	3.3	-12.9
16	68.0	-7.8	1.2
17	66.0	11.3	6.0
18	6.9	-1.5	-4.7
19	6.1	-0.6	-3.2
20	10.9	-1.8	-2.9
21	5.2	-0.6	-3.2
22	5.8	-1.0	-3.2
23	5.1	-0.5	-2.7
24	4.2	-0.3	-2.0
25	9.8	-1.0	-3.3
26	80.2	1.9	-3.5
27	42.7	-36.6	-34.2
28	45.8	-33.2	-31.6
29	48.6	-29.3	-30.0
30	52.4	-25.1	-26.4
31	55.9	-21.0	-23.3
32	59.9	-15.8	-19.8
33	63.4	-11.8	-16.9
34	65.7	-9.8	-14.6
35	68.7	-7.2	-12.0
36	71.1	-4.4	-10.3
37	73.7	-2.7	-7.9
38	75.6	-1.4	-6.9
39	78.4	0.5	-5.2
40	30.0	40.9	-3.5
41	32.3	39.8	-3.7
42	36.6	37.8	-5.0
43	41.3	32.6	-4.5
44	47.4	26.9	-6.1
45	53.7	22.0	-5.6
46	58.8	17.8	-5.9
47	61.4	15.0	-5.8
48	65.0	12.2	-5.4
49	68.8	9.3	-5.8
50	72.6	6.7	-5.0

ID	L*	a*	b*
51	75.1	5.4	-3.9
52	77.7	3.8	-4.8
53	78.0	-0.4	68.6
54	77.2	-1.5	58.8
55	77.0	-0.9	49.5
56	77.2	-1.3	42.1
57	77.3	-1.3	32.9
58	78.1	-0.6	25.2
59	78.4	-0.6	17.1
60	78.8	-0.2	14.5
61	79.5	-0.1	11.3
62	80.1	0.6	6.6
63	79.4	1.1	2.6
64	80.0	1.4	0.6
65	80.2	1.6	-1.6
66	16.3	-0.8	-1.8
67	22.5	-0.6	-1.1
68	27.6	-0.7	-1.4
69	32.2	-1.1	-1.7
70	38.4	-1.7	-1.7
71	45.8	-0.6	-3.5
72	53.5	-0.6	-4.5
73	57.8	-0.5	-3.9
74	62.0	0.5	-4.7
75	66.9	0.6	-4.0
76	71.1	0.9	-3.1
77	74.1	1.7	-4.2
78	77.8	1.8	-4.1
79	24.9	29.7	-16.2
80	26.2	20.7	-1.9
81	30.5	35.6	6.4
82	28.8	18.9	8.4
83	50.1	21.2	47.0
84	42.8	1.5	31.6
85	26.0	1.6	1.0
86	57.8	-22.5	48.5
87	34.1	-27.3	8.5
88	33.2	-39.9	-13.0
89	28.8	-24.3	-16.0
90	31.5	-21.1	-35.1
91	22.5	4.4	-21.4
92	23.6	20.4	-17.3
93	31.2	25.7	-1.9
94	33.1	24.5	5.9
95	29.9	26.6	8.3
96	37.0	24.1	16.7
97	37.5	23.8	23.3
98	56.2	0.3	30.1
99	41.1	-22.9	24.8
100	40.2	-22.4	9.2

ID	L*	a*	b*
101	31.8	-34.3	-2.1
102	37.9	-20.6	-15.1
103	27.9	-10.6	-28.4
104	32.3	7.1	-19.5
105	20.6	7.1	-2.2
106	29.0	15.2	-0.8
107	42.8	10.9	-1.0
108	20.1	4.9	0.6
109	45.0	10.1	8.2
110	33.3	1.4	14.0
111	42.9	0.6	17.0
112	58.6	1.4	9.6
113	57.4	1.5	-0.8
114	23.9	-12.5	2.0
115	34.4	-12.7	5.2
116	47.8	-8.4	3.1
117	20.3	-11.6	-5.7
118	42.6	3.9	-7.6
119	20.4	1.0	-10.0
120	48.6	-6.9	-7.7
121	31.8	-9.5	-6.0
122	4.5	-0.3	-2.1
123	6.3	-0.9	-3.4
124	8.1	-1.3	-3.9
125	5.0	-0.4	-2.4
126	8.9	-1.4	-3.8
127	12.2	-1.6	-3.1
128	15.4	-2.2	-2.3
129	5.9	-0.8	-3.2
130	11.6	-1.3	-3.1
131	15.5	-2.8	-2.2
132	21.4	-3.4	-1.7
133	26.8	-4.0	-1.6
134	6.8	-1.2	-3.6
135	15.0	-1.7	-2.2
136	22.5	-2.9	-2.0
137	28.7	-2.8	-1.3
138	35.2	-3.5	-2.7
139	40.7	-3.2	-3.7
140	8.9	-1.3	-3.5
141	18.5	-1.7	-2.0
142	28.1	-1.7	-1.4
143	35.9	-1.9	-3.1
144	47.6	-2.8	-3.5
145	54.9	-1.9	-4.3
146	9.1	-1.2	-3.5
147	20.3	-1.1	-1.4
148	30.7	-1.3	-1.7
149	41.1	-1.7	-2.7
150	54.3	-1.3	-4.2

ID	L*	a*	b*
151	62.3	-0.6	-4.7
152	15.4	-4.8	-3.3
153	23.6	-4.8	-2.6
154	32.0	-3.0	-2.7
155	44.8	-3.0	-3.9
156	60.8	-1.3	-5.2
157	70.3	-0.2	-3.9
158	75.2	0.9	-3.6
159	32.1	-31.3	-27.9
160	26.8	28.1	-3.4
161	60.8	-2.0	60.3
162	22.2	13.8	-35.5
163	35.7	-37.8	12.1
164	31.4	26.3	12.7
165	40.8	4.0	-16.7
166	46.2	-16.3	5.5
167	40.9	15.1	13.3
168	18.5	10.0	-27.0
169	32.5	-28.8	8.3
170	26.5	14.7	6.1
171	34.1	3.8	-14.0
172	36.7	-13.5	4.3
173	34.6	12.6	11.6
174	21.3	-14.4	-14.6
175	16.5	2.9	-2.1
176	34.3	-2.6	19.2
177	10.6	-1.6	-6.8
178	19.7	-12.5	0.3
179	15.9	1.5	-1.1
180	22.6	0.5	-7.8
181	23.0	-9.6	1.7
182	23.2	4.5	2.6

Appendix D07. Colorimetric Data Sheet for Sample No. 07 (Delta L* = -20).

ID	L*	a*	b*
1	42.2	-39.2	-36.9
2	30.3	43.0	-2.8
3	79.2	-0.6	78.0
4	25.1	14.2	-42.9
5	41.4	-49.5	16.9
6	36.7	41.6	21.7
7	16.9	0.1	-1.4
8	35.9	9.3	-32.3
9	47.5	-34.5	13.6
10	43.3	36.5	26.8
11	49.8	5.3	-19.9
12	55.5	21.3	16.1
13	43.1	1.7	2.0
14	60.4	-18.7	5.6
15	63.3	3.1	-12.7
16	69.3	-7.9	1.3
17	67.7	10.9	6.8
18	7.8	-2.0	-5.1
19	5.8	-0.8	-3.2
20	12.5	-1.8	-2.6
21	5.1	-0.6	-3.1
22	6.2	-1.2	-3.2
23	5.7	-0.8	-3.1
24	4.5	-0.1	-2.2
25	11.6	-0.7	-2.7
26	80.8	2.0	-3.9
27	44.6	-37.4	-35.4
28	47.5	-33.4	-33.3
29	51.0	-29.7	-30.7
30	54.2	-25.5	-26.2
31	57.8	-20.6	-22.8
32	60.9	-16.5	-19.8
33	65.3	-12.2	-16.1
34	66.8	-10.5	-14.6
35	69.5	-7.9	-11.9
36	71.8	-4.9	-9.9
37	74.9	-2.9	-8.2
38	76.6	-1.9	-6.6
39	78.9	0.6	-5.6
40	31.8	44.5	-3.6
41	34.5	43.0	-3.9
42	39.7	39.5	-5.6
43	44.3	33.8	-6.4
44	50.1	28.5	-6.2
45	55.7	22.5	-5.2
46	60.8	17.9	-5.6
47	63.3	15.4	-5.8
48	66.6	12.8	-6.5
49	70.5	9.3	-5.0
50	74.3	7.2	-4.6

ID	L*	a*	b*
51	75.8	5.8	-5.0
52	79.1	4.0	-5.1
53	78.2	-0.1	69.4
54	77.5	-0.6	60.0
55	77.6	-0.5	49.4
56	77.4	-0.7	42.4
57	77.9	-0.7	32.6
58	78.1	-1.0	25.7
59	78.8	-0.1	16.6
60	79.0	-0.3	15.0
61	79.8	0.3	10.2
62	80.2	0.7	7.0
63	79.8	1.1	3.0
64	80.2	1.3	1.1
65	80.4	1.7	-2.0
66	18.4	-0.6	-1.3
67	25.1	-0.1	-0.8
68	30.7	-0.6	-2.0
69	35.1	-0.8	-1.8
70	41.2	-0.5	-2.2
71	48.4	-0.5	-2.5
72	56.0	-0.3	-4.0
73	59.3	-0.2	-3.2
74	63.4	0.0	-4.2
75	67.9	0.5	-4.2
76	72.9	1.2	-4.4
77	75.0	0.8	-3.8
78	78.2	1.7	-4.9
79	25.3	32.2	-16.9
80	26.8	24.8	-3.3
81	31.9	40.1	7.0
82	30.7	22.5	10.2
83	51.3	21.6	48.7
84	43.2	1.7	31.8
85	29.8	2.6	1.0
86	57.9	-23.1	49.1
87	34.8	-30.7	9.9
88	35.2	-44.7	-13.0
89	30.5	-26.7	-16.6
90	32.5	-21.4	-36.5
91	23.8	5.5	-23.1
92	23.6	22.1	-19.1
93	32.9	28.1	-2.9
94	34.6	27.2	5.8
95	31.1	30.5	9.7
96	39.0	26.5	19.3
97	38.5	24.7	25.7
98	56.9	1.0	30.0
99	41.6	-24.1	26.3
100	41.2	-23.4	9.1

ID	L*	a*	b*
101	33.6	-37.4	-2.0
102	40.9	-19.3	-16.4
103	28.4	-10.6	-29.0
104	33.7	6.3	-20.0
105	22.1	9.7	-2.7
106	31.4	17.5	-0.5
107	45.8	11.6	-2.0
108	23.0	7.8	2.4
109	47.9	9.8	9.1
110	34.0	1.2	14.9
111	44.3	0.9	17.1
112	59.6	0.7	10.7
113	59.1	1.2	-0.9
114	26.4	-14.4	2.7
115	38.0	-12.5	5.6
116	50.0	-8.8	3.0
117	24.0	-13.4	-6.2
118	44.8	4.0	-9.2
119	21.1	1.3	-10.9
120	50.6	-6.5	-7.8
121	34.6	-11.0	-6.2
122	4.6	-0.3	-2.6
123	7.1	-1.0	-3.8
124	9.3	-2.0	-3.6
125	5.1	-0.5	-2.9
126	8.9	-1.5	-3.6
127	13.2	-2.3	-2.6
128	18.7	-3.1	-1.7
129	6.6	-0.8	-3.5
130	13.3	-1.6	-2.4
131	18.5	-3.2	-1.7
132	24.5	-4.0	-1.7
133	30.1	-4.2	-2.5
134	8.2	-1.4	-3.7
135	17.1	-2.0	-1.8
136	25.5	-3.3	-2.0
137	32.0	-3.0	-2.8
138	38.3	-4.1	-3.5
139	43.0	-3.7	-3.7
140	10.5	-1.0	-3.1
141	22.3	-0.8	-1.2
142	31.2	-1.9	-2.4
143	39.4	-1.8	-3.2
144	50.2	-2.7	-4.2
145	56.8	-2.0	-4.7
146	10.9	-1.2	-3.0
147	24.0	-0.7	-1.1
148	33.5	-1.6	-2.0
149	43.4	-2.0	-3.2
150	56.9	-1.0	-4.4

ID	L*	a*	b*
151	63.8	-0.7	-4.4
152	18.3	-5.7	-3.3
153	27.4	-5.3	-2.8
154	35.6	-3.7	-2.6
155	46.9	-4.3	-4.1
156	62.8	-1.2	-5.2
157	71.6	0.1	-5.1
158	75.9	0.7	-3.5
159	33.6	-32.8	-29.6
160	27.8	32.6	-3.7
161	61.1	-1.7	60.3
162	21.8	14.3	-35.9
163	37.1	-39.9	12.6
164	32.6	30.0	14.8
165	41.3	4.3	-17.8
166	48.2	-16.4	5.7
167	43.4	15.9	13.6
168	18.6	10.4	-27.3
169	34.2	-32.5	9.4
170	29.0	19.2	8.8
171	34.5	2.9	-14.4
172	38.8	-14.5	3.7
173	36.5	13.2	13.4
174	22.6	-15.4	-15.6
175	17.7	4.7	-2.3
176	35.1	-2.4	19.9
177	11.0	-1.4	-6.8
178	22.0	-14.1	1.4
179	17.6	2.8	-0.3
180	24.3	2.0	-8.9
181	26.3	-10.2	1.9
182	25.7	6.6	3.8

Appendix D08. Colorimetric Data Sheet for Sample No. 08 (Delta L* = -15).

ID	L*	a*	b*
1	45.0	-39.5	-38.6
2	32.4	48.4	-2.3
3	79.3	-1.3	77.9
4	25.7	13.9	-42.5
5	43.0	-53.5	19.5
6	38.2	45.6	25.6
7	18.8	-0.4	-0.9
8	37.7	9.0	-31.6
9	49.8	-35.0	13.4
10	46.2	37.9	28.9
11	51.6	4.8	-21.5
12	57.6	21.1	15.4
13	45.0	1.8	1.1
14	62.4	-17.8	5.7
15	64.6	3.2	-12.3
16	70.9	-7.7	1.2
17	69.1	11.1	7.5
18	8.4	-2.2	-4.9
19	6.6	-1.0	-3.5
20	13.1	-2.1	-1.6
21	5.5	-0.8	-3.6
22	6.8	-1.5	-3.2
23	6.6	-1.0	-3.4
24	4.5	-0.2	-2.1
25	14.0	-0.9	-1.7
26	81.7	2.0	-4.4
27	47.7	-37.8	-35.4
28	49.4	-34.8	-33.6
29	52.7	-30.3	-30.5
30	56.3	-26.1	-27.0
31	59.5	-21.5	-24.0
32	62.8	-16.9	-19.4
33	66.5	-12.3	-16.1
34	68.7	-9.8	-13.5
35	71.3	-7.5	-11.5
36	73.6	-4.8	-9.9
37	76.3	-2.5	-7.8
38	78.0	-1.3	-6.7
39	80.1	0.8	-5.6
40	35.3	50.2	-2.2
41	37.9	46.9	-2.7
42	43.4	42.5	-3.9
43	47.7	36.1	-4.7
44	53.4	29.3	-5.3
45	57.8	23.7	-5.9
46	63.2	18.1	-5.5
47	65.8	15.8	-5.7
48	68.9	12.5	-5.5
49	72.2	9.4	-5.1
50	75.4	7.2	-4.6

ID	L*	a*	b*
51	77.9	5.7	-4.2
52	79.9	3.1	-4.0
53	78.7	-0.4	68.5
54	77.6	-0.9	60.8
55	77.7	-1.3	49.9
56	77.6	-0.9	41.7
57	78.0	-1.3	33.9
58	78.6	-0.9	25.5
59	78.7	-0.6	16.7
60	79.6	-0.1	15.1
61	80.4	0.5	10.1
62	80.8	0.4	6.5
63	80.5	0.8	3.8
64	81.3	1.7	0.6
65	81.6	1.3	-1.0
66	21.6	-0.5	-0.7
67	28.1	-0.8	-0.4
68	33.8	-1.1	-1.5
69	38.5	-1.3	-1.4
70	43.8	-1.2	-2.0
71	51.0	-0.9	-3.2
72	58.7	-0.5	-3.6
73	61.6	-0.4	-4.2
74	65.9	0.4	-3.8
75	70.2	0.6	-3.1
76	73.9	1.4	-5.0
77	75.8	1.2	-3.7
78	79.3	1.9	-4.2
79	26.9	34.9	-16.6
80	27.6	28.2	-2.4
81	33.9	45.1	9.6
82	31.7	25.9	12.2
83	53.2	23.0	51.9
84	43.9	1.2	32.8
85	32.7	2.2	2.5
86	59.1	-22.5	49.4
87	36.7	-33.8	11.9
88	38.4	-47.0	-13.9
89	31.7	-29.3	-17.0
90	34.0	-22.3	-37.3
91	24.0	5.3	-23.9
92	24.9	24.3	-20.1
93	36.0	29.7	-1.8
94	36.7	28.4	5.9
95	32.3	35.0	10.9
96	40.5	26.8	20.3
97	40.3	25.9	29.5
98	58.3	1.2	31.5
99	43.4	-24.1	27.4
100	43.2	-24.2	8.8

ID	L*	a*	b*
101	35.6	-39.2	-2.1
102	43.3	-21.2	-16.5
103	30.1	-11.4	-29.0
104	35.0	6.1	-21.0
105	25.1	14.5	-2.4
106	33.0	18.8	-0.6
107	49.5	11.5	-2.3
108	25.9	12.5	4.5
109	50.2	10.5	9.3
110	35.2	1.7	16.8
111	45.2	1.1	18.5
112	61.1	1.1	10.6
113	61.2	1.8	-0.5
114	29.8	-15.5	3.8
115	39.6	-14.0	5.9
116	53.2	-8.0	3.6
117	26.1	-15.4	-7.0
118	47.5	3.2	-8.7
119	22.5	0.8	-11.0
120	53.5	-7.1	-7.2
121	37.6	-12.0	-8.0
122	5.1	-0.3	-2.6
123	7.5	-1.0	-3.5
124	10.3	-1.9	-3.9
125	6.2	-1.1	-3.3
126	10.3	-2.0	-3.6
127	15.7	-2.6	-2.3
128	20.9	-3.7	-1.8
129	7.7	-1.0	-3.7
130	14.2	-1.9	-2.6
131	20.8	-3.6	-2.1
132	28.1	-4.4	-1.0
133	33.4	-4.4	-2.1
134	9.4	-1.5	-3.5
135	18.8	-3.1	-1.8
136	27.8	-4.0	-1.6
137	34.8	-3.7	-2.2
138	41.7	-3.3	-2.9
139	45.5	-3.7	-4.4
140	12.1	-1.2	-2.6
141	25.0	-1.8	-1.4
142	34.6	-1.5	-1.7
143	41.8	-2.6	-3.5
144	53.7	-1.7	-4.2
145	59.3	-2.1	-3.8
146	12.5	-1.1	-2.6
147	27.0	-0.9	-1.0
148	36.3	-2.6	-1.9
149	46.3	-2.0	-3.6
150	59.3	-1.3	-3.6

ID	L*	a*	b*
151	66.4	0.1	-4.1
152	21.5	-7.7	-3.6
153	30.7	-5.6	-3.5
154	38.6	-4.5	-3.5
155	50.6	-3.2	-4.2
156	64.8	-1.8	-4.8
157	73.6	0.6	-5.3
158	77.6	1.0	-4.6
159	36.0	-35.3	-30.9
160	28.8	36.5	-3.3
161	61.7	-2.6	60.8
162	22.6	13.6	-35.5
163	38.8	-42.6	14.8
164	34.0	33.9	16.6
165	43.3	3.6	-18.0
166	50.4	-15.8	5.1
167	45.8	16.6	13.6
168	19.2	11.0	-27.8
169	35.4	-36.4	11.5
170	31.4	23.1	11.6
171	36.4	2.8	-14.6
172	41.0	-15.1	3.7
173	38.4	13.5	13.5
174	23.8	-17.6	-16.7
175	19.2	6.4	-2.2
176	35.9	-2.7	21.5
177	11.8	-1.2	-7.0
178	24.6	-16.2	2.4
179	19.7	4.5	0.9
180	25.4	1.9	-9.8
181	29.2	-10.5	2.9
182	28.5	8.2	6.3

Appendix D09. Colorimetric Data Sheet for Sample No. 09 (Delta L* = -10).

ID	L*	a*	b*
1	46.9	-40.3	-39.9
2	35.6	54.8	-1.0
3	79.7	-0.7	79.3
4	26.0	13.7	-42.6
5	45.5	-54.6	19.9
6	40.3	49.5	29.4
7	20.5	-0.5	-0.4
8	37.5	9.1	-31.8
9	52.2	-35.1	13.2
10	47.1	40.0	30.9
11	52.9	5.4	-21.2
12	60.1	21.7	16.1
13	47.6	1.5	1.8
14	63.9	-19.1	6.8
15	66.3	4.0	-11.9
16	72.0	-7.5	0.8
17	70.3	10.8	8.7
18	9.6	-2.3	-5.0
19	7.2	-1.1	-3.7
20	12.9	-2.4	-1.7
21	5.7	-0.9	-3.9
22	7.6	-2.0	-3.3
23	6.8	-0.9	-3.5
24	4.9	-0.4	-2.6
25	14.8	-0.5	-1.5
26	81.9	2.1	-4.1
27	49.6	-38.1	-38.3
28	52.0	-33.1	-35.6
29	54.5	-30.8	-31.9
30	57.9	-26.5	-27.1
31	61.8	-21.1	-23.4
32	64.5	-16.6	-20.1
33	68.1	-12.2	-17.2
34	70.3	-9.7	-15.3
35	72.8	-6.3	-12.5
36	74.7	-4.6	-10.2
37	77.4	-2.6	-8.5
38	78.8	-1.6	-7.1
39	81.1	1.3	-6.1
40	38.2	55.1	-2.4
41	41.7	49.7	-2.4
42	46.1	44.2	-5.0
43	50.6	37.1	-6.4
44	56.3	30.1	-5.9
45	60.0	24.5	-5.9
46	64.9	18.3	-6.4
47	67.2	16.0	-6.2
48	70.6	13.1	-5.1
49	73.1	9.8	-6.0
50	76.6	7.6	-4.9

ID	L*	a*	b*
51	78.3	5.7	-5.2
52	80.6	3.4	-5.0
53	78.9	-0.9	69.9
54	77.9	-0.8	59.5
55	77.8	-1.6	51.1
56	77.9	-0.9	41.8
57	78.2	-1.1	32.7
58	78.5	-0.5	25.6
59	79.2	0.0	17.4
60	79.7	-0.3	16.1
61	80.8	0.9	10.8
62	80.4	0.9	6.9
63	81.0	1.2	2.6
64	81.5	1.4	0.5
65	82.1	1.6	-1.8
66	23.3	-1.2	0.1
67	31.1	-1.3	-0.5
68	36.3	-1.4	-1.0
69	41.3	-1.8	-1.2
70	47.2	-1.0	-2.3
71	53.9	-0.9	-3.1
72	60.4	-0.7	-3.3
73	63.5	0.0	-3.5
74	67.8	0.7	-3.8
75	70.9	0.4	-3.5
76	75.1	0.8	-3.6
77	77.8	1.2	-4.2
78	79.9	2.1	-4.0
79	27.0	37.2	-18.1
80	28.9	32.3	-2.6
81	35.8	51.1	11.2
82	33.3	30.0	15.0
83	55.2	23.7	54.3
84	45.1	1.7	34.0
85	35.0	1.8	2.3
86	59.5	-22.5	50.5
87	38.1	-34.2	11.9
88	40.7	-50.5	-14.1
89	33.1	-31.1	-17.9
90	35.1	-23.1	-38.7
91	25.3	5.5	-23.9
92	24.9	26.3	-21.0
93	39.1	31.3	-2.8
94	39.1	30.0	6.1
95	33.1	39.2	11.8
96	42.8	27.8	20.7
97	41.6	27.1	32.2
98	58.7	0.8	32.1
99	44.5	-25.1	29.0
100	45.7	-24.0	9.2

ID	L*	a*	b*
101	36.9	-42.4	-2.3
102	45.9	-20.8	-17.2
103	30.1	-12.2	-29.6
104	36.5	7.3	-20.8
105	26.2	16.8	-2.5
106	35.7	19.0	0.1
107	52.1	11.8	-1.4
108	28.5	15.3	6.3
109	53.0	10.2	8.7
110	36.1	0.7	17.5
111	46.2	0.9	18.7
112	61.9	0.9	11.3
113	62.9	2.4	-0.8
114	31.7	-18.0	5.5
115	41.2	-14.6	6.3
116	55.2	-8.1	3.4
117	28.6	-16.1	-8.1
118	49.7	3.9	-8.7
119	23.5	2.3	-11.8
120	56.0	-6.5	-7.8
121	40.1	-12.2	-7.2
122	5.3	-0.3	-2.8
123	8.7	-1.7	-3.5
124	11.0	-2.3	-3.4
125	6.6	-0.9	-3.3
126	12.0	-2.0	-3.1
127	16.8	-3.1	-2.3
128	23.2	-4.6	-1.6
129	8.8	-1.3	-3.5
130	16.0	-2.0	-2.1
131	23.5	-4.4	-1.1
132	30.7	-4.3	-2.4
133	36.0	-5.0	-2.4
134	11.0	-1.3	-2.9
135	21.4	-2.7	-1.7
136	30.9	-3.3	-2.5
137	37.7	-3.9	-3.2
138	44.2	-4.2	-3.6
139	48.5	-3.9	-3.5
140	13.0	-0.9	-2.7
141	26.9	-1.6	-2.1
142	36.0	-2.6	-2.6
143	45.2	-1.9	-4.0
144	55.7	-2.6	-4.7
145	61.2	-1.7	-4.5
146	13.8	-0.9	-2.1
147	29.2	-1.2	-1.1
148	39.2	-1.5	-2.5
149	48.8	-2.7	-2.8
150	61.3	-1.0	-5.0

ID	L*	a*	b*
151	68.0	0.0	-4.3
152	24.4	-8.0	-3.9
153	33.2	-6.0	-3.4
154	41.6	-4.5	-3.8
155	53.0	-3.4	-5.0
156	66.9	-1.0	-5.1
157	74.8	0.2	-4.1
158	78.5	1.3	-4.2
159	37.8	-36.6	-32.7
160	29.8	40.2	-3.9
161	62.6	-2.2	61.6
162	22.4	13.7	-36.0
163	40.0	-45.5	15.9
164	35.2	37.0	19.0
165	44.6	2.9	-17.5
166	52.2	-17.1	5.1
167	48.3	17.3	13.6
168	19.3	10.6	-28.7
169	36.4	-38.2	12.2
170	31.7	25.2	12.6
171	37.4	3.3	-15.5
172	42.9	-16.0	3.7
173	40.3	14.0	13.5
174	25.3	-18.9	-18.4
175	20.9	9.2	-1.8
176	36.6	-2.5	23.1
177	12.0	-0.9	-7.5
178	26.9	-19.2	3.5
179	21.6	6.7	2.7
180	26.6	1.5	-10.1
181	31.8	-11.6	3.4
182	30.8	9.1	7.6

Appendix D10. Colorimetric Data Sheet for Sample No. 10 (Delta L* = -05).

ID	L*	a*	b*
1	48.9	-40.3	-40.5
2	38.5	60.2	-0.8
3	80.0	-0.5	78.1
4	25.5	14.4	-43.1
5	46.4	-57.9	20.7
6	42.3	54.6	32.3
7	22.5	-0.3	-0.2
8	38.0	9.1	-32.2
9	54.4	-35.6	13.0
10	50.3	41.5	30.2
11	54.0	5.3	-21.4
12	62.0	23.3	15.6
13	50.1	2.5	0.9
14	65.3	-18.7	7.4
15	67.4	3.6	-12.5
16	73.6	-7.8	1.5
17	71.6	11.7	6.7
18	9.6	-2.8	-5.5
19	8.5	-1.4	-3.9
20	14.0	-2.5	-1.3
21	5.9	-1.0	-3.9
22	8.2	-3.0	-3.3
23	8.6	-1.5	-3.6
24	5.1	-0.5	-2.6
25	15.9	-0.6	-2.0
26	82.7	1.9	-3.6
27	51.1	-38.4	-39.0
28	53.5	-34.8	-36.2
29	56.8	-30.3	-32.6
30	59.7	-26.6	-30.2
31	62.8	-22.0	-25.0
32	65.5	-17.4	-21.4
33	69.5	-12.0	-17.1
34	71.2	-9.8	-15.8
35	74.1	-7.0	-12.9
36	76.2	-4.6	-10.5
37	78.3	-2.5	-9.0
38	79.6	-1.2	-7.6
39	81.7	1.0	-5.5
40	41.6	59.1	-2.7
41	44.9	52.8	-3.5
42	49.3	45.4	-5.5
43	53.3	39.4	-5.7
44	57.9	31.6	-5.8
45	62.2	25.0	-6.0
46	67.2	19.0	-6.5
47	69.3	16.1	-6.2
48	72.2	13.3	-5.7
49	74.8	10.3	-5.5
50	77.7	7.0	-4.9

ID	L*	a*	b*
51	79.5	5.9	-5.2
52	81.6	3.9	-4.9
53	79.1	-0.6	69.0
54	78.0	-0.7	60.1
55	78.7	-1.1	48.9
56	78.3	-1.1	43.4
57	78.6	-1.2	34.0
58	79.1	-0.7	25.1
59	79.8	-0.3	17.3
60	79.9	-0.3	15.2
61	81.0	0.7	10.3
62	80.8	0.7	6.3
63	81.6	1.2	2.5
64	82.4	1.0	1.8
65	82.5	1.9	-2.3
66	25.4	-0.9	-0.5
67	33.2	-0.7	-0.8
68	39.0	-1.5	-1.5
69	43.4	-2.0	-2.1
70	49.5	-1.5	-2.3
71	56.3	-0.7	-3.9
72	62.5	0.3	-4.6
73	65.9	0.1	-3.2
74	69.6	0.8	-3.7
75	72.9	1.3	-5.1
76	76.3	1.2	-3.3
77	78.3	1.3	-4.2
78	80.9	1.7	-4.5
79	28.0	40.4	-19.2
80	29.3	36.0	-2.9
81	38.7	57.4	13.2
82	34.2	33.7	17.2
83	56.2	25.6	55.9
84	45.3	1.4	34.4
85	37.6	2.4	1.4
86	60.2	-22.9	51.1
87	39.3	-35.8	12.1
88	44.3	-51.5	-15.8
89	34.5	-32.1	-19.3
90	36.2	-23.4	-40.8
91	25.3	5.0	-25.1
92	25.6	27.8	-22.0
93	42.0	32.5	-3.2
94	42.3	30.7	6.1
95	34.1	42.5	12.3
96	44.4	29.8	21.3
97	43.3	28.3	34.9
98	59.9	1.4	31.4
99	45.2	-26.5	28.9
100	47.5	-25.2	9.3

ID	L*	a*	b*
101	39.3	-44.2	-3.3
102	48.0	-21.7	-18.3
103	30.3	-12.0	-31.7
104	36.3	6.9	-22.6
105	27.8	20.9	-2.8
106	37.6	19.7	-1.9
107	55.2	12.5	-3.0
108	30.2	18.4	8.0
109	55.3	12.7	8.6
110	37.0	1.0	17.8
111	47.7	0.9	17.9
112	62.8	1.9	11.7
113	64.5	2.8	-0.8
114	34.3	-18.4	5.9
115	42.5	-15.2	6.7
116	57.0	-8.1	2.6
117	30.5	-18.4	-8.9
118	52.2	3.9	-9.7
119	24.1	2.3	-12.6
120	58.0	-5.7	-7.8
121	42.2	-12.7	-8.5
122	5.4	-0.6	-2.9
123	9.2	-1.6	-3.4
124	12.6	-2.6	-3.0
125	7.0	-1.0	-3.5
126	13.0	-1.7	-2.5
127	19.6	-2.9	-1.6
128	25.6	-4.6	-2.1
129	9.5	-1.0	-3.5
130	17.1	-2.3	-1.6
131	26.6	-4.0	-0.9
132	33.1	-4.0	-2.1
133	39.1	-4.3	-3.6
134	11.9	-1.4	-2.9
135	23.8	-2.8	-1.2
136	33.4	-3.5	-2.6
137	40.8	-3.9	-3.5
138	47.2	-4.4	-3.8
139	51.7	-3.6	-5.0
140	15.7	-0.3	-1.9
141	29.5	-2.8	-1.6
142	38.7	-2.6	-3.6
143	47.4	-2.9	-4.0
144	57.9	-2.1	-4.3
145	63.3	-1.4	-4.8
146	15.8	-0.6	-1.7
147	31.3	-1.6	-1.5
148	41.4	-2.8	-3.0
149	51.9	-1.8	-3.4
150	63.4	-0.3	-4.9

ID	L*	a*	b*
151	69.5	-0.2	-3.8
152	26.8	-9.1	-4.1
153	36.1	-5.9	-3.4
154	43.7	-5.1	-3.6
155	55.2	-4.1	-5.1
156	68.3	-1.1	-4.9
157	75.5	0.0	-4.3
158	79.3	1.6	-5.2
159	40.0	-37.8	-33.6
160	30.8	44.5	-4.1
161	62.7	-2.3	61.9
162	22.4	13.9	-36.4
163	41.9	-48.3	16.2
164	36.8	41.2	22.8
165	45.9	3.4	-18.6
166	55.2	-16.1	4.8
167	51.1	18.0	14.8
168	19.3	10.9	-28.7
169	37.5	-41.0	13.3
170	32.5	28.0	14.1
171	38.2	3.1	-15.8
172	45.3	-14.7	4.2
173	41.8	14.4	12.8
174	26.0	-19.5	-19.6
175	22.5	11.0	-1.7
176	37.3	-2.9	24.2
177	12.4	-0.6	-7.6
178	29.1	-21.8	4.4
179	23.8	9.1	4.0
180	28.0	1.5	-11.1
181	33.4	-12.0	3.2
182	32.6	10.1	9.2

Appendix D00. Colorimetric Data Sheet for Sample No. 00 (Delta L* = 00).

ID	L*	a*	b*
1	50.9	-40.3	-42.4
2	42.5	68.3	-1.0
3	80.0	-0.1	77.4
4	26.2	14.4	-43.2
5	48.6	-59.8	19.5
6	45.3	61.0	36.9
7	24.2	-0.3	-1.3
8	39.0	9.6	-32.1
9	56.3	-37.5	12.6
10	52.4	43.9	30.5
11	55.5	5.4	-22.2
12	64.5	23.5	15.6
13	52.7	2.6	1.0
14	66.8	-19.5	5.4
15	68.7	3.9	-13.2
16	74.4	-8.0	1.5
17	73.6	11.8	5.2
18	10.7	-3.1	-5.4
19	9.8	-1.3	-3.8
20	15.1	-2.7	-1.2
21	6.3	-0.9	-4.6
22	9.1	-3.9	-3.6
23	8.4	-1.5	-3.8
24	5.2	-0.4	-2.7
25	17.7	-0.9	-1.4
26	83.5	1.7	-3.4
27	53.2	-39.2	-40.2
28	55.5	-35.5	-37.9
29	58.5	-31.0	-34.2
30	61.7	-26.2	-30.1
31	64.5	-21.4	-26.0
32	67.3	-16.6	-22.4
33	70.9	-12.6	-17.4
34	72.6	-9.6	-15.4
35	74.7	-6.5	-12.9
36	76.8	-4.3	-10.7
37	79.3	-2.3	-8.3
38	80.5	-1.4	-6.9
39	82.0	0.8	-5.4
40	44.7	63.0	-3.3
41	48.7	55.9	-4.8
42	52.0	48.0	-6.8
43	56.3	40.7	-7.4
44	60.0	34.2	-8.4
45	64.9	26.2	-7.5
46	68.9	19.7	-6.6
47	70.8	17.1	-6.1
48	73.4	13.5	-5.6
49	76.1	10.0	-5.7
50	79.0	7.8	-6.2

ID	L*	a*	b*
51	80.6	5.7	-5.0
52	82.0	3.3	-4.8
53	79.5	-0.3	68.7
54	78.7	-0.7	59.4
55	78.5	-1.4	48.9
56	78.6	-1.2	41.2
57	79.1	-1.2	33.9
58	79.3	-0.4	23.8
59	80.2	0.1	17.2
60	80.5	0.0	15.0
61	81.2	0.4	10.1
62	81.6	0.9	7.6
63	81.9	1.2	2.7
64	82.8	1.0	1.7
65	83.6	1.6	-2.2
66	27.9	-0.7	-0.8
67	34.7	-0.9	-2.3
68	41.1	-1.6	-2.6
69	47.1	-0.8	-3.7
70	52.9	-0.6	-4.1
71	58.9	-0.6	-4.2
72	64.8	0.1	-4.2
73	68.1	0.5	-4.4
74	70.8	0.5	-3.9
75	74.2	1.1	-4.6
76	77.3	1.4	-5.0
77	79.3	1.6	-4.8
78	81.7	1.8	-5.1
79	28.8	43.7	-21.6
80	30.1	40.6	-4.5
81	42.8	66.4	16.8
82	35.3	38.3	18.2
83	58.0	26.8	57.4
84	46.5	1.5	34.2
85	39.8	2.9	0.9
86	61.3	-22.5	49.7
87	40.1	-37.1	11.8
88	47.4	-55.2	-15.0
89	36.7	-33.2	-20.3
90	37.4	-24.0	-41.8
91	25.9	5.8	-27.3
92	25.5	29.3	-23.4
93	45.6	34.9	-4.2
94	45.7	33.9	6.4
95	36.5	50.0	15.2
96	47.2	31.6	21.1
97	45.5	30.7	37.6
98	60.7	2.2	31.0
99	47.0	-25.1	28.6
100	49.6	-26.1	8.8

ID	L*	a*	b*
101	41.4	-47.9	-2.9
102	51.1	-21.7	-18.8
103	31.0	-13.2	-31.8
104	37.8	6.6	-22.0
105	28.4	24.2	-4.3
106	41.0	20.7	-1.4
107	58.2	14.7	-2.7
108	31.8	23.2	8.5
109	58.0	13.4	8.3
110	37.6	2.3	17.3
111	48.5	0.5	17.1
112	64.0	1.9	10.6
113	66.3	3.1	-1.4
114	35.7	-21.9	6.0
115	44.2	-16.2	6.2
116	59.5	-8.2	2.1
117	32.6	-20.4	-9.4
118	53.9	4.2	-10.0
119	24.7	2.6	-13.4
120	60.3	-6.4	-9.3
121	45.7	-12.6	-10.2
122	5.7	-0.8	-3.1
123	10.4	-1.4	-3.8
124	14.0	-2.9	-3.0
125	8.2	-1.2	-3.8
126	14.2	-2.3	-2.2
127	20.8	-3.4	-2.2
128	28.2	-4.5	-2.5
129	10.3	-0.8	-3.2
130	18.6	-3.0	-1.8
131	28.3	-4.6	-2.5
132	35.1	-4.9	-2.7
133	41.9	-5.7	-3.9
134	13.9	-0.1	-2.3
135	26.0	-3.5	-2.3
136	35.4	-3.9	-3.5
137	43.1	-4.4	-4.2
138	50.7	-3.8	-4.6
139	54.2	-3.5	-5.4
140	16.4	-0.1	-1.7
141	31.7	-1.1	-2.9
142	41.4	-3.1	-3.9
143	50.5	-2.8	-5.0
144	60.4	-1.4	-5.4
145	65.4	-2.0	-6.1
146	16.6	-0.4	-1.3
147	33.5	-1.8	-2.2
148	44.3	-2.7	-3.5
149	55.4	-1.5	-4.7
150	65.8	-0.5	-4.4

ID	L*	a*	b*
151	71.5	0.0	-4.7
152	28.7	-9.9	-6.1
153	37.7	-7.0	-4.2
154	47.1	-5.4	-4.5
155	58.1	-3.6	-5.7
156	70.4	-0.7	-5.5
157	77.2	0.6	-5.8
158	80.1	1.4	-4.5
159	42.2	-38.1	-36.8
160	33.0	50.7	-3.2
161	63.2	-1.7	61.7
162	22.9	13.9	-36.4
163	43.2	-51.8	16.9
164	38.4	45.8	25.3
165	46.8	4.5	-20.3
166	56.6	-18.4	4.9
167	54.1	19.5	14.2
168	19.1	11.6	-29.4
169	38.5	-43.9	14.3
170	33.5	32.6	15.7
171	39.5	2.7	-16.1
172	46.6	-16.0	4.0
173	44.6	15.2	11.8
174	27.4	-20.7	-20.9
175	23.7	14.7	-2.9
176	37.6	-2.4	24.7
177	13.4	0.1	-8.1
178	31.8	-26.4	6.2
179	25.3	11.5	5.2
180	29.4	1.6	-12.3
181	35.7	-12.2	3.9
182	34.3	11.7	10.3

Appendix D11. Colorimetric Data Sheet for Sample No. 11 (Delta L* = +05).

ID	L*	a*	b*
1	53.2	-41.0	-42.1
2	45.4	70.9	0.1
3	80.7	-0.5	79.6
4	25.8	14.2	-43.1
5	50.6	-59.8	20.5
6	46.3	62.9	39.1
7	26.5	-0.6	-0.2
8	39.5	9.4	-32.8
9	59.1	-36.9	13.5
10	55.3	44.2	31.0
11	56.7	5.6	-21.5
12	66.3	23.4	16.7
13	55.8	3.2	0.5
14	68.2	-18.7	5.4
15	69.4	4.1	-12.9
16	75.5	-8.7	1.8
17	74.5	11.4	6.9
18	11.6	-3.3	-5.2
19	9.9	-1.3	-3.7
20	15.7	-2.7	-0.2
21	6.2	-1.1	-4.4
22	10.0	-4.1	-2.9
23	8.8	-1.3	-3.5
24	5.7	-0.4	-2.7
25	19.1	0.1	-0.4
26	83.6	1.6	-3.3
27	55.3	-39.1	-39.9
28	57.4	-36.4	-37.2
29	60.3	-31.9	-34.2
30	62.8	-26.7	-30.2
31	66.0	-21.8	-25.3
32	68.5	-17.2	-22.1
33	71.8	-12.8	-18.2
34	74.0	-9.9	-15.8
35	76.1	-7.2	-13.1
36	78.4	-4.8	-10.9
37	80.4	-2.9	-7.7
38	81.4	-1.0	-6.7
39	82.9	0.6	-5.0
40	47.4	64.8	-3.6
41	51.8	57.6	-4.6
42	54.6	49.2	-8.1
43	58.6	41.9	-7.8
44	62.5	33.2	-7.1
45	66.4	26.6	-6.6
46	70.3	20.1	-6.1
47	72.8	18.1	-6.3
48	75.5	14.1	-6.7
49	77.4	10.8	-6.5
50	79.6	7.5	-5.3

ID	L*	a*	b*
51	81.1	5.4	-5.0
52	83.0	3.1	-4.0
53	79.9	-0.6	70.5
54	78.4	-0.9	60.3
55	78.4	-1.2	50.8
56	78.4	-1.6	42.9
57	79.2	-1.1	33.8
58	79.2	-0.7	25.6
59	80.5	-0.5	18.3
60	80.9	-0.1	15.2
61	81.5	0.6	10.2
62	81.8	0.4	7.6
63	83.2	1.1	3.4
64	83.3	0.9	2.5
65	83.7	2.0	-2.0
66	29.5	-0.5	-0.7
67	36.9	-1.2	-1.3
68	42.7	-1.2	-2.4
69	49.3	-2.1	-2.5
70	56.0	-0.6	-4.0
71	61.1	-0.5	-4.2
72	67.2	0.2	-4.4
73	69.8	0.1	-3.1
74	72.8	1.0	-5.1
75	75.7	1.0	-3.5
76	78.7	1.6	-4.5
77	80.3	1.6	-3.8
78	82.3	1.9	-3.9
79	30.2	45.1	-23.3
80	31.4	42.0	-3.7
81	45.1	68.7	18.5
82	36.1	39.6	19.5
83	59.9	27.0	59.3
84	47.1	1.5	36.0
85	41.4	2.8	2.0
86	61.4	-22.8	51.7
87	41.9	-38.2	12.8
88	51.2	-55.2	-16.8
89	38.4	-35.2	-20.0
90	39.3	-23.4	-43.9
91	26.5	5.4	-26.8
92	26.3	29.8	-23.8
93	49.5	36.9	-2.9
94	49.2	35.6	6.3
95	38.1	52.0	16.6
96	50.1	32.4	21.7
97	47.6	32.7	39.9
98	60.8	2.1	32.6
99	47.9	-27.4	30.5
100	52.5	-27.3	9.5

ID	L*	a*	b*
101	44.4	-50.3	-1.9
102	54.3	-22.3	-19.4
103	32.0	-13.5	-31.6
104	39.0	6.7	-21.3
105	29.2	24.3	-3.8
106	44.5	22.0	-1.4
107	61.2	14.9	-2.4
108	32.8	23.4	9.7
109	60.8	12.8	8.1
110	37.8	1.0	18.5
111	49.3	1.2	18.6
112	64.5	1.8	12.3
113	68.6	2.6	-1.8
114	37.5	-22.2	7.8
115	46.4	-16.1	7.2
116	61.4	-8.8	2.8
117	34.7	-20.7	-9.5
118	56.2	4.0	-10.2
119	25.7	2.4	-13.4
120	62.7	-6.9	-9.2
121	48.4	-13.7	-8.9
122	6.2	-0.8	-3.3
123	10.7	-1.6	-3.3
124	14.6	-3.3	-2.8
125	8.2	-1.3	-3.6
126	15.5	-2.1	-1.9
127	23.2	-3.8	-1.4
128	30.6	-5.5	-2.1
129	11.1	-0.7	-3.0
130	21.0	-2.2	-1.4
131	30.3	-4.7	-1.9
132	38.0	-5.2	-2.4
133	43.6	-6.4	-3.4
134	14.6	-0.6	-1.7
135	27.7	-2.9	-1.4
136	37.4	-4.4	-3.1
137	45.5	-4.3	-3.8
138	53.6	-4.7	-4.5
139	57.5	-3.3	-5.1
140	17.3	-0.4	-1.5
141	33.8	-2.0	-1.5
142	44.1	-3.3	-3.9
143	54.2	-2.7	-4.5
144	62.5	-2.1	-5.2
145	67.4	-1.3	-4.8
146	17.8	-0.3	-0.8
147	35.4	-1.7	-1.7
148	47.0	-2.5	-3.5
149	57.6	-1.5	-4.4
150	67.5	-0.6	-4.6

ID	L*	a*	b*
151	73.2	0.5	-5.6
152	31.3	-10.1	-4.8
153	40.0	-7.3	-4.5
154	50.2	-5.1	-4.5
155	60.5	-3.1	-5.3
156	72.3	-0.5	-6.1
157	78.3	1.0	-5.4
158	80.8	1.2	-4.2
159	44.3	-40.1	-37.0
160	35.2	54.4	-3.4
161	63.8	-1.7	62.8
162	22.7	13.6	-36.2
163	44.8	-53.8	17.8
164	39.3	47.9	26.9
165	48.8	4.0	-18.9
166	58.8	-18.0	5.1
167	56.8	19.8	14.3
168	19.3	11.8	-29.2
169	40.2	-43.9	14.9
170	34.2	34.2	16.8
171	40.6	3.0	-15.4
172	49.5	-16.7	4.8
173	46.2	15.1	12.3
174	27.8	-22.0	-21.5
175	24.6	16.6	-3.0
176	37.6	-3.8	25.4
177	13.4	-0.3	-8.4
178	33.3	-28.3	7.1
179	26.7	14.0	7.0
180	29.6	1.5	-12.7
181	37.9	-14.1	4.4
182	36.3	11.3	11.4

Appendix D12. Colorimetric Data Sheet for Sample No. 12 (Delta L* = +10).

ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*
1	54.3	-39.9	-43.4	51	81.3	5.7	-4.6	101	47.2	-52.1	-1.9	151	74.1	0.4	-4.4
2	48.1	74.1	0.7	52	83.2	3.7	-3.9	102	55.7	-23.9	-20.7	152	31.7	-10.3	-5.1
3	80.3	0.2	79.1	53	79.4	0.0	71.7	103	31.4	-12.9	-32.1	153	40.9	-7.1	-3.9
4	24.9	15.1	-43.2	54	77.9	-0.4	62.3	104	38.8	8.3	-23.2	154	52.4	-5.2	-4.9
5	51.7	-60.1	21.7	55	78.4	-0.7	50.8	105	29.8	25.2	-3.2	155	62.4	-3.1	-4.9
6	48.6	65.6	41.3	56	78.4	-1.1	44.7	106	46.9	24.9	-1.7	156	73.4	-1.0	-4.8
7	27.9	0.7	0.4	57	79.1	-1.1	35.9	107	63.4	15.4	-2.2	157	79.0	1.4	-4.9
8	38.1	10.4	-33.4	58	79.7	-0.3	26.2	108	33.0	24.6	9.7	158	81.5	1.4	-5.0
9	60.2	-38.5	14.2	59	80.2	-0.3	19.3	109	62.1	13.8	9.9	159	46.0	-39.4	-38.3
10	57.8	46.3	33.2	60	81.0	0.1	15.6	110	37.8	2.9	18.2	160	37.1	58.3	-2.7
11	57.0	6.1	-21.9	61	81.5	0.5	11.3	111	50.0	2.0	19.9	161	63.3	-1.4	63.7
12	67.7	24.9	17.4	62	82.3	1.0	7.9	112	64.7	2.6	12.2	162	22.1	14.3	-36.1
13	57.7	3.1	1.5	63	83.2	1.6	4.1	113	69.7	3.7	-0.6	163	45.8	-53.5	18.7
14	69.2	-19.3	6.3	64	83.4	1.2	2.2	114	37.0	-21.6	7.6	164	40.2	51.1	28.8
15	69.9	4.5	-14.4	65	84.3	2.0	-1.0	115	47.8	-16.8	8.0	165	48.8	4.5	-18.8
16	76.6	-7.8	1.1	66	30.6	-0.6	-0.3	116	62.8	-8.6	4.4	166	60.1	-18.0	5.8
17	75.3	12.2	8.6	67	37.5	-1.0	-0.7	117	34.4	-20.4	-9.2	167	58.8	20.9	14.6
18	11.4	-3.0	-5.3	68	45.2	-0.4	-2.3	118	57.5	5.1	-10.2	168	18.6	11.7	-28.7
19	11.1	-0.5	-3.5	69	51.7	-0.5	-2.8	119	25.4	2.7	-13.8	169	40.1	-45.3	15.6
20	16.0	-1.8	-0.3	70	58.0	-0.6	-2.7	120	64.1	-6.2	-8.6	170	34.8	37.5	19.5
21	6.1	-0.8	-4.4	71	63.2	-0.1	-4.0	121	50.1	-14.5	-9.7	171	40.4	3.7	-16.5
22	9.9	-4.1	-3.6	72	68.8	0.6	-3.9	122	6.2	-0.7	-3.4	172	51.4	-16.0	5.3
23	9.4	-1.1	-3.7	73	71.0	0.4	-4.2	123	11.2	-1.4	-3.2	173	48.8	16.7	14.4
24	5.7	-0.6	-3.3	74	74.1	1.1	-4.2	124	15.0	-2.5	-2.7	174	27.9	-22.2	-21.3
25	19.3	0.6	-0.4	75	76.7	1.0	-4.4	125	8.2	-1.3	-3.9	175	25.1	20.5	-2.3
26	84.5	2.0	-3.5	76	79.3	2.0	-4.1	126	15.3	-1.7	-2.2	176	37.3	-2.2	25.7
27	56.8	-38.3	-41.3	77	80.6	1.9	-4.7	127	23.2	-4.1	-1.7	177	12.8	0.4	-9.1
28	59.0	-36.0	-38.2	78	82.6	1.7	-3.7	128	31.1	-4.5	-2.1	178	33.4	-30.1	8.0
29	62.0	-30.9	-34.1	79	31.0	47.0	-22.4	129	11.4	-1.0	-3.5	179	27.4	15.9	7.9
30	64.0	-26.6	-30.9	80	32.2	43.3	-3.4	130	21.2	-2.4	-1.7	180	29.7	1.7	-11.8
31	66.4	-21.6	-26.7	81	47.8	71.4	20.8	131	31.1	-4.3	-2.1	181	38.4	-14.4	5.2
32	69.3	-17.4	-22.0	82	37.1	42.2	20.6	132	39.1	-5.6	-1.5	182	36.5	11.6	10.9
33	72.7	-12.4	-17.9	83	60.9	29.4	60.9	133	46.1	-4.5	-2.6				
34	74.7	-9.6	-15.8	84	47.4	2.8	36.6	134	14.4	-0.4	-1.9				
35	76.9	-6.8	-12.8	85	42.2	2.9	1.8	135	28.4	-2.5	-1.2				
36	79.2	-4.7	-10.4	86	61.4	-23.6	52.7	136	39.2	-3.1	-2.8				
37	81.6	-2.5	-7.9	87	42.3	-39.8	14.1	137	47.3	-3.7	-3.1				
38	82.0	-1.1	-7.6	88	53.4	-55.0	-15.0	138	55.8	-3.6	-4.2				
39	83.7	0.7	-5.7	89	39.8	-35.9	-20.2	139	59.4	-2.8	-4.8				
40	49.7	66.3	-3.2	90	39.4	-24.3	-44.0	140	17.4	0.5	-1.4				
41	54.2	61.1	-5.5	91	25.7	6.4	-26.5	141	34.0	-2.1	-1.3				
42	57.5	50.5	-7.3	92	25.9	30.1	-24.1	142	45.5	-2.5	-3.4				
43	60.6	44.6	-6.3	93	52.2	39.4	-4.2	143	56.0	-2.2	-4.1				
44	64.1	34.8	-7.2	94	52.8	37.2	6.7	144	64.4	-2.1	-5.4				
45	68.0	27.6	-6.8	95	39.9	55.6	18.9	145	68.9	-1.1	-4.5				
46	71.7	21.4	-7.1	96	52.4	35.4	23.7	146	18.8	0.3	-0.9				
47	74.1	18.2	-6.6	97	49.5	33.8	41.3	147	35.4	-1.2	-1.9				
48	76.3	14.4	-6.2	98	60.9	1.9	32.5	148	48.7	-1.8	-2.4				
49	78.2	10.6	-5.7	99	48.4	-27.5	31.3	149	59.8	-1.0	-4.0				
50	80.7	7.3	-4.5	100	54.1	-28.4	10.7	150	69.3	0.2	-3.4				

Appendix D13. Colorimetric Data Sheet for Sample No. 13 (Delta L* = +15).

ID	L*	a*	b*
1	56.3	-38.5	-44.7
2	49.8	74.8	-0.6
3	80.3	-0.1	79.7
4	25.2	14.6	-43.0
5	54.0	-58.5	21.9
6	50.1	68.0	43.9
7	28.8	0.2	-0.5
8	39.2	10.1	-32.9
9	62.3	-38.4	15.1
10	60.1	46.5	31.8
11	58.4	6.5	-22.4
12	69.7	24.8	15.5
13	60.1	3.5	1.6
14	70.2	-19.5	6.4
15	70.8	4.2	-13.7
16	77.9	-8.3	1.7
17	76.3	12.7	7.5
18	12.6	-3.7	-5.5
19	11.3	0.0	-3.5
20	16.0	-1.9	-0.2
21	6.5	-0.9	-4.5
22	11.1	-4.8	-3.1
23	10.1	-0.9	-3.6
24	6.1	-0.7	-3.5
25	21.1	0.5	0.3
26	84.8	2.0	-4.0
27	58.7	-37.2	-42.6
28	61.5	-34.4	-39.6
29	63.2	-30.2	-35.8
30	65.4	-26.1	-30.8
31	68.0	-22.3	-26.9
32	70.7	-17.7	-23.0
33	74.4	-12.2	-18.3
34	75.8	-9.8	-14.9
35	78.0	-7.4	-12.5
36	79.9	-4.4	-9.9
37	82.2	-2.5	-7.9
38	82.9	-0.8	-7.3
39	84.3	0.6	-5.3
40	52.6	67.3	-2.8
41	56.9	61.6	-4.5
42	60.2	52.1	-7.6
43	63.2	44.7	-8.5
44	66.4	35.3	-8.3
45	70.1	29.0	-7.6
46	73.6	21.9	-7.1
47	75.9	18.5	-6.3
48	77.9	14.7	-6.4
49	79.8	11.2	-5.7
50	81.6	8.0	-4.8

ID	L*	a*	b*
51	82.4	6.0	-4.9
52	84.0	4.1	-4.4
53	79.4	-0.1	71.6
54	78.4	0.1	62.0
55	78.4	-1.0	51.8
56	78.3	-1.0	43.9
57	79.1	-1.2	36.0
58	79.8	-0.6	27.2
59	80.3	-0.2	19.8
60	81.3	0.0	15.9
61	82.1	0.5	12.1
62	82.5	0.8	8.0
63	83.5	1.0	4.2
64	83.9	1.4	2.3
65	84.6	1.8	-1.1
66	31.9	-0.9	-0.4
67	39.8	-0.8	-1.0
68	47.4	-1.3	-1.9
69	55.5	-1.1	-3.4
70	60.8	-0.4	-4.1
71	65.8	0.0	-4.3
72	70.8	0.6	-4.4
73	73.1	1.1	-4.9
74	75.3	0.8	-3.3
75	77.9	1.4	-4.8
76	80.8	1.8	-4.7
77	81.9	2.2	-4.3
78	83.5	1.5	-3.7
79	32.7	48.8	-23.4
80	34.5	46.9	-3.6
81	50.1	73.4	22.2
82	38.5	45.1	22.1
83	62.7	29.8	62.5
84	48.2	3.0	37.5
85	43.9	3.1	1.6
86	62.0	-22.7	52.9
87	43.5	-42.1	14.6
88	56.9	-52.9	-15.5
89	43.2	-37.8	-20.1
90	41.5	-24.7	-45.3
91	26.2	5.5	-26.6
92	26.9	31.3	-23.8
93	55.6	41.1	-4.0
94	56.0	40.0	7.0
95	43.2	60.9	21.7
96	55.8	35.7	23.6
97	51.6	36.3	43.7
98	61.5	2.2	33.5
99	50.5	-27.4	32.0
100	56.5	-28.8	11.1

ID	L*	a*	b*
101	50.3	-53.6	-1.5
102	58.2	-23.4	-21.3
103	32.3	-12.5	-33.2
104	39.9	7.2	-23.9
105	30.7	26.7	-4.5
106	51.6	25.7	-1.4
107	66.5	16.3	-3.9
108	34.3	25.4	9.5
109	65.0	14.4	8.6
110	37.7	1.8	18.3
111	50.9	2.1	19.8
112	65.8	1.8	12.3
113	71.5	2.9	-0.3
114	38.1	-22.4	7.9
115	50.4	-16.0	7.1
116	65.5	-8.6	2.2
117	35.6	-21.7	-10.2
118	59.6	5.7	-10.0
119	26.1	3.3	-13.7
120	67.0	-6.5	-9.5
121	53.7	-14.8	-9.3
122	6.7	-0.6	-3.5
123	11.0	-2.1	-3.4
124	15.5	-3.3	-3.0
125	8.9	-1.1	-3.6
126	16.6	-1.8	-1.6
127	25.9	-4.5	-1.2
128	33.3	-4.1	-1.8
129	12.0	-0.7	-2.8
130	23.5	-3.0	-0.9
131	33.2	-4.2	-1.3
132	41.6	-5.5	-2.1
133	48.4	-4.9	-3.3
134	16.0	0.2	-1.9
135	30.1	-2.8	-1.9
136	40.5	-4.2	-3.2
137	50.3	-4.3	-4.1
138	58.9	-3.3	-5.1
139	62.2	-3.5	-5.0
140	18.7	0.2	-1.3
141	36.2	-1.7	-2.4
142	48.0	-2.7	-3.2
143	58.8	-2.2	-4.4
144	67.2	-1.0	-4.9
145	71.5	-0.8	-5.7
146	19.9	0.3	-0.6
147	37.9	-0.9	-1.9
148	52.1	-1.8	-3.6
149	62.5	-0.9	-4.7
150	71.2	0.1	-5.6

ID	L*	a*	b*
151	76.2	0.7	-5.3
152	33.2	-10.5	-4.8
153	43.3	-7.5	-3.7
154	55.7	-4.5	-4.4
155	65.1	-3.6	-6.0
156	75.0	-0.5	-6.2
157	80.7	1.2	-5.3
158	82.2	1.5	-4.0
159	48.5	-40.2	-39.4
160	40.0	62.6	-2.2
161	63.8	-1.3	63.7
162	22.0	14.5	-35.9
163	47.5	-55.5	19.8
164	42.5	55.5	31.4
165	50.2	4.3	-19.1
166	62.7	-17.7	5.9
167	62.1	21.8	15.2
168	19.1	11.6	-28.7
169	41.4	-47.9	16.0
170	36.0	40.2	21.0
171	41.7	4.1	-16.9
172	53.9	-18.1	5.2
173	52.3	18.1	14.0
174	28.4	-23.7	-21.8
175	25.8	22.8	-2.9
176	37.6	-3.3	26.2
177	13.6	0.5	-9.2
178	34.1	-31.9	9.5
179	29.0	19.2	9.7
180	31.4	2.4	-12.3
181	39.7	-14.6	4.9
182	37.6	10.9	10.3

Appendix D14. Colorimetric Data Sheet for Sample No. 14 (Delta L* = +20).

ID	L*	a*	b*
1	58.1	-37.8	-44.3
2	51.6	74.5	-0.9
3	80.5	-0.6	80.4
4	26.1	14.4	-42.6
5	56.8	-56.0	20.2
6	51.9	68.6	44.3
7	31.3	0.3	0.4
8	40.4	9.7	-32.4
9	64.9	-36.9	15.0
10	63.2	46.8	32.3
11	59.9	6.8	-23.2
12	71.8	25.0	16.9
13	63.7	4.5	1.5
14	72.3	-19.5	8.1
15	72.4	4.1	-13.2
16	79.1	-8.2	2.2
17	78.3	12.7	7.8
18	13.7	-4.2	-5.5
19	13.1	0.4	-3.2
20	17.7	-1.9	0.8
21	7.0	-1.1	-4.8
22	12.2	-5.0	-2.6
23	11.6	-0.4	-2.9
24	6.4	-0.8	-3.5
25	22.8	0.4	0.6
26	86.2	1.9	-3.3
27	60.8	-35.8	-41.6
28	63.2	-33.1	-38.4
29	65.0	-29.9	-35.9
30	67.5	-24.7	-31.0
31	70.2	-21.3	-27.2
32	72.9	-17.3	-23.3
33	76.2	-11.8	-18.3
34	77.7	-10.0	-16.3
35	79.7	-7.2	-13.1
36	81.3	-4.7	-10.1
37	83.6	-2.8	-7.5
38	84.1	-1.2	-6.7
39	85.1	0.7	-4.7
40	55.2	67.5	-4.1
41	59.8	60.7	-5.7
42	62.1	51.8	-7.0
43	65.8	44.2	-7.6
44	69.1	36.2	-7.9
45	71.7	28.5	-7.8
46	76.0	21.3	-6.7
47	77.5	18.2	-6.3
48	80.0	14.6	-5.6
49	81.6	10.5	-5.3
50	82.8	7.3	-5.5

ID	L*	a*	b*
51	84.0	6.0	-4.7
52	84.8	3.8	-4.5
53	79.8	-0.2	71.5
54	79.2	-0.7	60.9
55	78.8	-1.1	53.0
56	79.5	-0.9	44.7
57	79.7	-1.4	35.7
58	80.3	-0.8	26.0
59	81.3	-0.6	20.3
60	82.1	-0.1	15.6
61	82.2	0.7	11.2
62	83.5	1.0	7.8
63	83.7	1.3	4.4
64	84.5	1.5	0.2
65	85.4	1.7	-0.9
66	33.9	-0.7	-0.4
67	42.8	-0.7	-1.0
68	50.9	-1.5	-2.5
69	58.9	-0.5	-3.2
70	64.2	-0.6	-3.6
71	69.0	0.2	-3.7
72	73.1	1.1	-5.0
73	75.6	0.8	-3.3
74	77.8	1.6	-5.4
75	79.7	1.7	-3.9
76	81.7	1.6	-4.5
77	82.7	1.6	-4.1
78	84.7	1.8	-3.7
79	34.3	50.5	-24.6
80	37.7	51.0	-1.8
81	51.7	73.5	21.1
82	40.8	47.6	23.5
83	65.4	30.1	64.6
84	50.0	2.7	38.2
85	46.6	3.4	1.7
86	63.2	-22.9	53.7
87	46.0	-43.0	14.1
88	60.7	-48.8	-15.9
89	46.4	-39.1	-21.7
90	43.4	-25.5	-45.9
91	28.1	6.3	-26.2
92	28.2	31.5	-24.8
93	59.8	41.6	-4.8
94	60.1	40.6	7.3
95	46.0	64.4	22.2
96	59.5	36.4	22.9
97	55.2	37.3	45.5
98	63.4	1.5	34.4
99	52.7	-29.5	32.7
100	60.0	-28.5	10.7

ID	L*	a*	b*
101	53.9	-53.8	-1.5
102	61.3	-24.1	-21.9
103	33.5	-12.3	-33.6
104	42.8	7.7	-22.7
105	32.3	27.3	-4.3
106	55.5	27.5	-2.1
107	69.7	17.4	-3.3
108	35.9	26.7	10.9
109	67.7	14.8	7.8
110	39.2	1.9	19.0
111	52.8	1.7	19.8
112	67.4	1.9	12.8
113	74.1	3.3	-1.9
114	39.5	-24.6	7.8
115	53.8	-17.0	7.5
116	67.7	-7.9	3.3
117	38.6	-22.0	-10.0
118	62.0	5.7	-12.2
119	28.1	3.4	-14.0
120	69.5	-6.3	-9.4
121	57.6	-13.9	-11.5
122	7.2	-0.9	-4.1
123	12.5	-1.8	-3.2
124	17.6	-3.2	-2.5
125	9.5	-1.2	-3.5
126	18.4	-2.1	-1.4
127	28.1	-4.1	-1.2
128	35.3	-4.3	-1.9
129	12.7	-0.9	-2.7
130	26.5	-1.5	-0.5
131	36.0	-5.1	-1.7
132	44.4	-5.5	-2.0
133	51.8	-5.8	-4.5
134	17.3	0.2	-1.3
135	32.4	-3.4	-1.6
136	43.6	-3.8	-3.2
137	54.0	-3.6	-4.3
138	62.2	-3.3	-5.2
139	65.6	-3.6	-6.2
140	20.4	-0.2	-0.7
141	38.1	-2.3	-2.4
142	51.6	-3.1	-4.3
143	62.9	-1.8	-4.8
144	70.1	-0.9	-6.2
145	73.7	-1.0	-5.1
146	21.7	0.2	-0.7
147	40.6	-2.3	-1.4
148	55.5	-1.4	-4.1
149	66.4	-0.9	-4.9
150	74.2	-0.2	-4.5

ID	L*	a*	b*
151	78.3	0.5	-5.3
152	35.5	-11.9	-5.2
153	45.9	-8.0	-4.2
154	59.3	-5.0	-5.1
155	68.6	-3.1	-4.8
156	77.6	-0.3	-6.1
157	81.6	1.0	-5.2
158	83.3	1.2	-4.0
159	51.3	-40.2	-41.4
160	42.6	65.8	-2.6
161	64.6	-1.8	65.0
162	23.0	14.3	-35.8
163	49.9	-57.4	20.3
164	44.8	59.3	34.5
165	52.8	5.7	-20.9
166	65.1	-17.9	6.5
167	65.3	21.4	15.3
168	19.4	11.9	-29.0
169	43.4	-48.8	16.6
170	37.3	43.0	22.9
171	43.8	3.3	-16.4
172	57.9	-17.7	4.4
173	55.9	19.1	13.9
174	29.8	-25.0	-22.0
175	27.1	26.6	-2.5
176	38.6	-2.7	27.6
177	14.1	1.0	-9.6
178	35.6	-33.3	9.9
179	30.8	21.8	11.8
180	32.5	2.4	-12.7
181	42.0	-14.6	5.0
182	40.1	12.4	10.8

Appendix D15. Colorimetric Data Sheet for Sample No. 15 (Delta L* = +25).

ID	L*	a*	b*
1	60.0	-36.0	-44.1
2	52.7	73.8	0.2
3	80.6	-0.3	76.5
4	25.8	14.1	-43.2
5	58.8	-54.1	18.7
6	52.9	69.5	45.1
7	32.7	0.0	0.1
8	40.2	9.9	-33.0
9	66.9	-37.1	15.6
10	64.7	47.0	31.2
11	61.2	6.4	-22.7
12	73.5	25.8	17.9
13	66.2	4.4	1.4
14	73.3	-18.4	6.9
15	73.2	4.1	-13.4
16	80.1	-7.7	2.3
17	79.1	13.1	7.3
18	15.0	-5.0	-5.9
19	13.5	1.2	-3.2
20	17.5	-2.8	0.4
21	7.0	-1.0	-4.8
22	13.4	-6.4	-2.7
23	12.4	0.1	-3.0
24	7.0	-0.8	-3.8
25	24.0	0.6	0.3
26	86.9	1.8	-2.8
27	62.4	-34.7	-41.8
28	64.5	-32.2	-39.1
29	67.0	-27.5	-34.4
30	68.5	-24.2	-32.1
31	71.2	-21.3	-28.3
32	73.7	-17.9	-24.2
33	77.2	-12.2	-18.6
34	78.9	-10.7	-16.8
35	80.6	-7.5	-13.8
36	82.5	-4.8	-11.5
37	84.3	-2.5	-8.1
38	85.0	-1.4	-6.2
39	86.2	0.3	-4.3
40	56.9	66.4	-4.5
41	61.9	60.1	-5.6
42	64.6	49.6	-6.2
43	67.8	45.2	-7.3
44	70.4	37.3	-7.1
45	73.3	29.5	-7.0
46	77.5	22.5	-6.0
47	79.2	18.8	-5.5
48	80.7	14.5	-5.5
49	82.1	10.7	-5.0
50	83.8	7.5	-4.9

ID	L*	a*	b*
51	84.1	6.1	-4.7
52	85.5	3.5	-4.1
53	79.9	-0.1	71.6
54	79.3	-0.5	61.7
55	79.2	-0.1	50.2
56	79.3	-1.0	44.0
57	79.9	-1.3	35.1
58	80.4	-0.8	26.3
59	81.4	-0.4	20.2
60	82.1	-0.1	14.6
61	82.7	0.6	12.0
62	83.3	0.9	7.9
63	84.4	1.2	4.5
64	85.2	1.7	0.6
65	86.1	1.8	-1.3
66	35.3	-0.8	-0.6
67	44.4	-1.4	-1.5
68	54.5	-0.5	-3.0
69	61.6	-0.3	-4.2
70	67.8	0.1	-3.9
71	71.3	0.7	-5.4
72	75.3	0.6	-4.1
73	77.1	1.3	-5.6
74	79.2	1.5	-5.0
75	81.0	1.5	-5.4
76	82.9	1.9	-4.1
77	83.8	1.6	-4.0
78	85.1	2.1	-4.4
79	35.7	52.2	-26.1
80	39.8	53.8	-3.6
81	53.0	72.8	19.9
82	42.2	49.5	24.4
83	66.6	31.0	64.8
84	50.4	2.8	39.1
85	48.9	3.3	1.8
86	63.3	-23.4	53.9
87	47.8	-44.6	15.1
88	63.2	-45.4	-14.9
89	48.8	-40.1	-22.4
90	44.6	-25.2	-46.1
91	27.5	6.1	-27.4
92	28.4	32.9	-26.9
93	62.4	44.1	-4.8
94	63.6	41.1	5.5
95	48.7	67.5	24.1
96	62.2	37.8	23.3
97	57.8	39.3	47.4
98	63.8	1.5	33.3
99	53.8	-30.8	33.3
100	62.5	-29.0	11.0

ID	L*	a*	b*
101	57.3	-52.8	-2.5
102	63.8	-24.2	-22.8
103	34.3	-13.6	-33.4
104	42.9	7.0	-23.3
105	34.0	28.7	-3.4
106	59.0	28.8	-3.8
107	72.8	17.2	-3.6
108	36.7	27.4	10.5
109	70.1	14.6	9.4
110	39.4	2.1	19.1
111	53.9	1.9	19.1
112	67.8	2.1	12.3
113	75.9	3.7	-1.3
114	40.9	-24.4	8.3
115	56.5	-17.6	7.8
116	70.1	-7.8	4.8
117	40.0	-23.0	-11.0
118	64.3	6.1	-11.6
119	28.2	3.1	-14.1
120	72.5	-6.4	-9.6
121	60.5	-15.2	-10.9
122	7.5	-0.9	-3.9
123	12.8	-2.5	-2.8
124	19.4	-4.1	-2.6
125	10.1	-1.5	-3.3
126	19.5	-2.2	-1.6
127	29.4	-4.7	-1.7
128	37.1	-4.8	-2.4
129	14.1	-0.6	-2.0
130	26.8	-2.8	-1.1
131	37.1	-5.4	-2.5
132	45.8	-5.0	-2.8
133	55.2	-5.0	-4.2
134	17.8	-0.1	-1.2
135	33.6	-3.5	-1.7
136	45.2	-4.6	-3.4
137	56.6	-3.4	-4.9
138	65.3	-3.5	-5.8
139	68.6	-2.9	-5.7
140	21.9	-0.3	-1.1
141	40.2	-2.3	-2.7
142	55.0	-2.3	-4.3
143	65.4	-2.3	-5.4
144	72.4	-1.1	-6.0
145	75.8	-0.6	-6.4
146	23.9	1.1	0.7
147	42.4	-2.0	-2.3
148	58.1	-1.2	-3.7
149	69.2	-0.6	-4.1
150	76.1	0.4	-5.4

ID	L*	a*	b*
151	79.0	1.0	-5.7
152	36.6	-12.6	-6.5
153	48.6	-7.8	-5.1
154	62.2	-4.3	-5.6
155	71.4	-1.8	-6.7
156	79.0	0.2	-5.8
157	82.3	1.1	-4.8
158	84.2	1.3	-4.5
159	53.8	-40.3	-40.3
160	45.1	68.5	-3.0
161	64.7	-1.0	64.8
162	22.8	13.9	-36.1
163	51.8	-57.3	20.4
164	46.2	61.8	36.4
165	53.6	5.2	-20.7
166	67.2	-17.9	6.1
167	67.9	21.9	14.6
168	19.5	11.7	-28.5
169	44.5	-51.5	17.6
170	38.4	45.5	23.8
171	44.8	3.3	-16.6
172	60.8	-17.1	4.1
173	59.3	18.7	13.2
174	30.4	-25.7	-23.5
175	27.0	26.9	-2.8
176	39.2	-2.8	28.5
177	14.1	1.0	-9.9
178	36.3	-35.6	11.0
179	31.4	23.1	12.2
180	33.2	2.1	-14.1
181	43.6	-15.1	5.3
182	40.7	12.6	11.9

Appendix D16. Colorimetric Data Sheet for Sample No. 16 (Delta L* = +30).

ID	L*	a*	b*
1	61.3	-35.1	-42.9
2	54.6	72.9	-1.3
3	80.5	-0.2	77.3
4	26.1	14.7	-43.9
5	61.1	-52.2	16.8
6	53.7	69.3	41.9
7	34.0	0.8	-1.3
8	41.9	9.7	-33.0
9	68.4	-36.5	12.4
10	66.3	46.6	29.4
11	62.0	6.5	-22.9
12	75.3	26.4	15.4
13	69.0	4.2	-0.8
14	74.8	-17.8	6.2
15	74.5	4.7	-14.2
16	81.2	-7.5	0.1
17	80.2	12.4	6.8
18	15.4	-5.2	-6.6
19	15.1	2.1	-3.0
20	19.1	-2.2	0.7
21	7.5	-1.2	-5.1
22	14.1	-6.4	-2.8
23	13.4	0.3	-2.9
24	7.4	-1.0	-3.7
25	26.2	0.8	0.5
26	87.8	1.8	-2.5
27	63.6	-33.6	-40.9
28	65.9	-31.3	-37.9
29	68.2	-27.4	-35.0
30	70.2	-24.2	-31.2
31	72.5	-20.7	-28.1
32	75.3	-17.5	-24.6
33	78.5	-12.0	-19.4
34	80.3	-10.3	-16.7
35	81.8	-7.5	-13.7
36	83.4	-5.0	-11.3
37	84.7	-2.8	-9.7
38	86.1	-1.2	-7.8
39	87.2	0.4	-4.9
40	58.5	65.2	-5.1
41	63.6	58.3	-6.1
42	65.7	50.2	-7.9
43	69.3	44.5	-7.7
44	71.1	37.4	-8.1
45	75.1	29.4	-7.1
46	79.3	22.4	-6.6
47	80.9	19.1	-6.5
48	82.4	14.7	-5.6
49	83.5	10.9	-5.4
50	84.4	7.4	-5.0

ID	L*	a*	b*
51	85.3	5.6	-4.3
52	86.4	4.0	-3.6
53	80.1	-0.2	69.0
54	79.3	-0.6	59.8
55	79.3	-0.3	50.3
56	79.7	-0.3	42.3
57	80.3	-1.1	35.0
58	81.2	-0.4	25.3
59	82.1	-0.5	18.4
60	83.0	0.3	13.8
61	82.9	0.4	11.0
62	84.0	1.1	6.2
63	85.0	1.3	4.1
64	85.6	2.0	0.7
65	86.3	2.0	-2.1
66	37.1	0.4	-2.1
67	46.8	-0.6	-2.9
68	56.4	-0.6	-5.0
69	65.1	-0.8	-4.5
70	70.7	0.1	-5.6
71	74.7	0.6	-4.5
72	77.6	1.2	-5.9
73	79.1	1.1	-5.6
74	80.8	1.7	-5.2
75	81.8	1.8	-5.2
76	83.5	1.4	-3.9
77	84.4	2.1	-4.8
78	85.8	2.0	-4.0
79	37.7	53.5	-26.1
80	42.5	56.3	-3.9
81	54.1	73.1	18.3
82	44.1	51.5	23.7
83	68.1	31.2	63.8
84	51.5	2.4	38.6
85	51.6	3.8	0.5
86	64.7	-22.9	51.9
87	50.0	-45.3	14.1
88	65.4	-41.7	-15.0
89	51.8	-40.5	-24.3
90	46.4	-24.7	-48.0
91	28.2	6.5	-28.7
92	29.4	34.1	-27.5
93	65.4	46.0	-6.7
94	66.5	42.0	5.9
95	51.2	69.5	23.0
96	65.3	39.0	22.5
97	60.4	39.9	46.1
98	65.1	1.6	33.0
99	56.4	-28.9	32.8
100	64.8	-28.9	10.5

ID	L*	a*	b*
101	60.6	-49.3	-3.3
102	66.5	-23.3	-24.1
103	35.5	-13.4	-34.0
104	44.4	7.4	-25.7
105	35.4	30.2	-6.0
106	62.4	29.9	-3.7
107	75.3	18.5	-5.0
108	38.3	27.8	10.2
109	72.8	15.2	6.8
110	40.5	1.6	18.4
111	55.2	1.5	19.0
112	69.4	1.7	11.3
113	77.4	3.9	-1.4
114	42.4	-24.5	6.4
115	59.2	-17.8	6.3
116	72.6	-7.7	2.2
117	42.0	-24.0	-11.5
118	67.2	6.4	-12.0
119	28.8	2.6	-15.4
120	74.4	-5.6	-10.7
121	63.8	-15.1	-12.3
122	8.1	-1.2	-4.1
123	14.1	-1.8	-3.0
124	21.0	-4.3	-3.0
125	11.5	-1.0	-3.2
126	20.6	-2.9	-2.0
127	31.8	-4.6	-2.8
128	38.7	-5.0	-2.9
129	15.2	-0.8	-2.1
130	28.8	-3.2	-1.0
131	39.6	-5.5	-2.5
132	48.3	-6.4	-3.1
133	57.7	-5.2	-5.0
134	18.9	-0.4	-1.6
135	35.4	-3.5	-2.1
136	47.9	-5.2	-3.9
137	59.9	-3.4	-5.7
138	69.3	-2.5	-6.6
139	72.1	-2.4	-7.0
140	23.7	0.7	-0.6
141	41.8	-2.0	-3.4
142	57.4	-2.3	-4.8
143	68.9	-1.5	-5.1
144	75.2	-0.8	-6.7
145	77.9	-0.5	-6.6
146	24.5	0.5	-0.8
147	44.3	-1.9	-3.7
148	61.0	-1.3	-5.2
149	72.0	0.1	-6.1
150	78.4	0.8	-6.0

ID	L*	a*	b*
151	81.0	1.1	-6.2
152	38.5	-13.0	-7.3
153	51.7	-7.6	-6.0
154	65.6	-5.1	-6.3
155	74.1	-2.1	-7.1
156	80.5	0.0	-6.4
157	83.7	0.5	-5.0
158	85.2	1.9	-4.7
159	55.7	-40.3	-40.6
160	47.7	70.9	-3.0
161	65.8	-0.8	65.4
162	23.0	14.4	-36.6
163	54.5	-56.8	19.2
164	48.4	64.2	36.4
165	55.2	5.2	-19.7
166	69.5	-17.2	5.1
167	70.4	23.0	13.7
168	19.5	11.7	-29.2
169	46.0	-53.6	17.7
170	40.0	48.1	24.6
171	46.0	3.6	-18.9
172	63.5	-18.2	4.7
173	62.7	19.3	12.7
174	31.3	-26.2	-24.5
175	27.1	28.7	-4.2
176	39.9	-3.0	28.8
177	15.0	1.6	-10.1
178	37.4	-36.5	10.5
179	32.4	24.6	12.5
180	34.1	2.6	-13.9
181	45.0	-15.3	4.5
182	41.6	12.5	10.4

Appendix D17. Colorimetric Data Sheet for Sample No. 17 (Delta L* = +35).

ID	L*	a*	b*
1	62.7	-34.3	-42.6
2	55.9	71.6	-1.9
3	80.6	-0.6	78.2
4	26.7	13.9	-43.4
5	62.7	-50.0	16.1
6	54.6	68.6	43.0
7	34.8	-0.9	-1.4
8	41.9	9.3	-33.1
9	69.7	-36.1	13.3
10	67.3	46.7	29.4
11	63.0	6.2	-23.7
12	76.2	26.2	16.2
13	71.7	4.5	1.6
14	75.6	-18.2	7.3
15	75.4	4.3	-13.6
16	82.1	-7.8	1.9
17	81.2	13.0	8.1
18	16.9	-7.3	-6.7
19	16.3	2.3	-2.1
20	19.8	-3.0	2.0
21	7.7	-1.7	-4.7
22	15.7	-8.3	-1.6
23	14.5	0.5	-1.7
24	7.7	-1.5	-3.4
25	26.7	-0.2	1.1
26	88.2	1.8	-2.3
27	64.7	-33.3	-39.6
28	67.2	-30.7	-36.8
29	69.4	-27.4	-34.2
30	71.5	-23.7	-31.0
31	73.9	-20.6	-27.7
32	76.1	-17.9	-24.1
33	79.7	-12.5	-18.9
34	80.8	-10.3	-17.4
35	82.5	-7.9	-13.8
36	84.2	-4.9	-11.0
37	86.1	-3.0	-8.9
38	86.8	-1.2	-8.0
39	87.6	0.6	-5.9
40	60.0	64.6	-4.8
41	64.4	57.4	-5.7
42	66.9	50.3	-6.9
43	70.9	44.2	-6.9
44	72.0	36.3	-7.6
45	76.1	29.5	-6.9
46	80.6	22.7	-6.6
47	81.7	19.3	-6.7
48	83.3	15.5	-5.9
49	84.7	11.2	-5.7
50	85.6	7.6	-4.7

ID	L*	a*	b*
51	86.0	5.6	-3.4
52	87.3	4.1	-3.6
53	80.4	-0.5	71.3
54	79.4	-1.0	60.9
55	79.5	-0.6	51.2
56	79.7	-0.5	42.8
57	80.5	-0.8	35.0
58	81.2	-0.5	25.4
59	82.3	0.3	19.4
60	83.1	0.4	14.5
61	83.6	0.1	12.8
62	84.2	1.3	6.5
63	85.4	1.6	3.3
64	86.4	1.8	2.1
65	87.3	1.8	-0.7
66	38.5	-1.8	-0.9
67	48.7	-1.9	-2.2
68	59.4	-0.5	-4.2
69	68.4	-0.1	-4.6
70	73.9	0.4	-5.1
71	76.8	1.0	-6.2
72	79.3	1.2	-5.4
73	81.0	1.5	-6.0
74	82.2	1.5	-4.4
75	83.2	1.5	-4.0
76	84.9	1.6	-4.4
77	85.6	1.9	-4.2
78	86.8	1.8	-3.0
79	39.8	55.4	-26.4
80	44.6	58.3	-5.4
81	55.4	70.8	16.3
82	45.8	52.7	25.5
83	69.5	31.1	63.8
84	52.7	2.6	39.1
85	54.3	3.6	-0.4
86	65.1	-23.5	52.6
87	52.1	-47.4	14.7
88	66.9	-39.7	-15.8
89	53.8	-42.3	-24.9
90	47.5	-25.3	-48.6
91	27.8	5.5	-28.5
92	30.1	34.0	-28.1
93	67.9	45.2	-6.0
94	69.0	42.6	5.2
95	53.0	70.0	23.3
96	67.4	39.7	21.4
97	63.1	39.3	45.7
98	65.9	1.1	33.8
99	58.1	-31.1	33.6
100	66.7	-29.3	11.7

ID	L*	a*	b*
101	63.2	-47.1	-2.9
102	68.1	-24.5	-23.4
103	35.5	-15.3	-34.4
104	44.9	7.4	-25.4
105	36.6	29.9	-6.6
106	65.8	30.3	-4.8
107	77.7	18.7	-3.6
108	39.5	27.7	10.7
109	74.6	15.7	8.5
110	41.3	1.1	18.8
111	56.5	1.2	18.6
112	70.1	2.4	11.0
113	79.0	3.8	-1.8
114	43.7	-26.7	7.0
115	62.1	-18.2	6.8
116	73.8	-7.5	3.3
117	42.8	-26.1	-12.2
118	68.8	5.7	-12.1
119	29.2	1.7	-16.0
120	76.7	-6.3	-10.6
121	67.0	-15.2	-13.7
122	8.9	-1.4	-3.6
123	15.4	-2.8	-2.4
124	22.7	-5.5	-3.0
125	12.2	-1.6	-2.9
126	22.3	-3.9	-1.5
127	32.9	-5.7	-2.6
128	39.6	-7.0	-3.3
129	15.3	-1.8	-2.4
130	29.0	-4.9	-2.0
131	40.7	-7.2	-3.0
132	50.7	-6.3	-4.6
133	60.6	-5.9	-5.3
134	20.2	-1.4	-1.5
135	37.0	-3.8	-3.3
136	50.3	-4.3	-4.7
137	62.8	-4.4	-5.3
138	72.1	-2.6	-6.5
139	75.0	-2.8	-6.7
140	24.4	-1.4	-0.9
141	43.5	-3.0	-3.9
142	59.4	-2.9	-5.1
143	71.4	-1.4	-6.4
144	77.6	-1.2	-6.4
145	79.7	-0.4	-7.0
146	26.2	-0.8	-0.1
147	46.7	-2.6	-3.6
148	64.1	-2.1	-5.0
149	74.9	-0.2	-5.2
150	80.3	0.7	-6.2

ID	L*	a*	b*
151	82.4	1.0	-5.3
152	39.5	-14.1	-7.0
153	53.6	-8.7	-6.1
154	68.8	-4.4	-6.8
155	76.6	-2.5	-6.5
156	81.7	0.1	-5.7
157	85.0	1.1	-5.0
158	86.0	1.3	-3.9
159	57.6	-38.8	-43.0
160	49.7	72.7	-3.9
161	66.2	-1.9	65.7
162	23.1	13.8	-36.5
163	56.9	-56.9	18.2
164	50.1	66.7	39.1
165	56.5	5.0	-21.6
166	70.3	-17.6	5.5
167	72.8	23.6	15.6
168	19.3	11.4	-29.4
169	46.6	-55.4	17.6
170	40.8	50.6	27.0
171	47.3	3.4	-19.5
172	66.3	-18.2	4.4
173	65.7	19.9	13.4
174	32.0	-28.4	-24.4
175	27.6	30.2	-4.5
176	40.0	-3.8	29.6
177	15.3	1.0	-10.6
178	38.1	-37.6	10.8
179	32.8	25.8	14.1
180	34.7	1.8	-14.1
181	46.3	-16.6	5.1
182	42.3	12.3	10.4

Appendix D18. Colorimetric Data Sheet for Sample No. 18 (Delta L* = +40).

ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*
1	64.2	-32.8	-41.4	51	87.6	6.4	-5.6	101	66.0	-43.7	-3.0	151	84.4	1.0	-5.7
2	57.7	69.3	-2.8	52	88.2	4.1	-5.1	102	70.6	-23.6	-23.6	152	41.9	-14.1	-7.1
3	80.6	-0.8	77.6	53	80.3	-0.8	68.5	103	37.8	-14.6	-36.1	153	56.8	-8.0	-7.3
4	27.0	13.8	-43.8	54	79.6	-1.0	59.1	104	47.5	7.5	-25.6	154	72.7	-4.3	-7.0
5	65.0	-46.2	14.6	55	80.0	-1.0	51.2	105	39.4	30.9	-6.1	155	79.7	-1.8	-7.8
6	55.1	68.0	41.2	56	80.6	-0.5	42.2	106	69.2	30.9	-4.8	156	84.1	0.0	-6.2
7	36.7	-1.2	-1.7	57	81.0	-0.8	34.1	107	80.3	18.9	-3.6	157	86.0	1.0	-4.6
8	42.6	10.6	-34.5	58	82.0	-0.2	26.4	108	41.4	28.8	10.7	158	87.1	1.3	-3.6
9	71.7	-33.7	10.9	59	82.6	0.2	19.0	109	77.2	15.6	7.3	159	59.8	-37.6	-42.2
10	67.9	45.2	27.3	60	83.3	0.7	14.4	110	42.2	0.8	19.6	160	51.7	72.7	-4.2
11	64.9	6.2	-22.8	61	83.8	0.2	12.3	111	58.6	1.9	18.5	161	67.0	-1.5	65.7
12	77.7	25.0	15.6	62	84.9	1.7	7.1	112	71.4	1.9	11.1	162	23.4	13.2	-36.9
13	75.2	4.5	-1.2	63	86.4	1.7	2.7	113	81.0	4.3	-2.4	163	59.2	-55.5	16.8
14	76.8	-18.0	7.6	64	87.0	1.7	2.1	114	45.7	-27.3	6.9	164	51.6	68.5	39.7
15	76.5	3.9	-13.2	65	88.6	1.6	-0.5	115	65.1	-18.0	6.8	165	58.7	5.6	-20.8
16	83.5	-7.5	1.8	66	40.4	-1.6	-1.7	116	75.8	-7.1	3.6	166	72.2	-16.7	5.9
17	82.1	12.2	6.4	67	52.2	-2.1	-3.2	117	46.9	-25.6	-12.7	167	75.2	23.9	13.3
18	18.1	-7.8	-6.8	68	62.4	-0.7	-5.1	118	70.9	6.5	-12.9	168	20.1	11.5	-29.8
19	16.9	2.5	-2.0	69	72.0	0.7	-6.2	119	30.8	2.7	-16.8	169	49.5	-56.4	17.4
20	20.7	-3.2	2.7	70	77.3	1.0	-6.8	120	78.8	-5.5	-11.1	170	43.0	54.0	29.6
21	7.7	-1.6	-4.9	71	79.6	0.9	-5.9	121	70.0	-15.9	-13.1	171	49.4	4.2	-18.7
22	17.3	-8.4	-1.2	72	81.8	1.3	-5.8	122	9.5	-1.9	-3.7	172	69.0	-17.6	3.6
23	15.7	1.6	-1.1	73	82.5	1.7	-5.3	123	15.9	-3.2	-2.7	173	69.0	20.1	11.8
24	9.0	-1.4	-2.9	74	83.8	1.2	-4.5	124	24.5	-5.6	-3.1	174	33.4	-29.1	-25.5
25	29.1	0.1	0.6	75	84.7	1.4	-5.1	125	12.9	-2.0	-2.6	175	28.4	32.7	-4.8
26	89.2	2.0	-4.1	76	86.0	1.7	-4.3	126	24.7	-4.1	-1.1	176	40.9	-3.9	30.3
27	66.3	-30.9	-39.1	77	86.3	1.5	-3.9	127	34.8	-5.5	-2.0	177	16.0	1.8	-11.8
28	68.7	-28.5	-36.1	78	88.4	1.4	-2.6	128	42.2	-6.5	-4.3	178	39.4	-39.2	9.9
29	70.2	-26.6	-33.5	79	41.5	55.1	-26.6	129	17.1	-1.5	-1.7	179	33.6	27.2	14.7
30	72.2	-23.2	-30.6	80	47.2	58.3	-5.9	130	31.7	-4.0	-2.3	180	36.8	2.3	-14.4
31	75.1	-20.3	-27.7	81	56.7	68.6	14.1	131	42.8	-6.8	-3.5	181	49.3	-16.6	4.3
32	77.4	-17.7	-24.4	82	48.2	55.1	26.5	132	54.1	-6.3	-4.1	182	45.6	11.8	10.6
33	81.0	-12.3	-19.5	83	71.2	30.5	62.8	133	64.0	-5.4	-6.1				
34	81.9	-9.9	-16.6	84	54.0	2.6	40.2	134	22.0	-1.0	-1.2				
35	83.3	-7.3	-14.5	85	57.2	3.2	-1.0	135	39.2	-4.5	-3.5				
36	85.7	-5.0	-11.2	86	66.2	-24.6	54.0	136	52.9	-5.8	-5.4				
37	86.8	-3.2	-9.0	87	55.0	-45.5	13.1	137	66.2	-4.3	-6.1				
38	87.7	-1.2	-7.9	88	68.4	-38.1	-16.2	138	75.7	-2.9	-6.8				
39	88.9	1.2	-5.8	89	57.3	-40.9	-26.4	139	78.0	-2.4	-7.3				
40	61.2	63.0	-5.1	90	49.4	-25.0	-48.3	140	26.5	-0.8	-0.4				
41	65.6	56.1	-5.6	91	30.0	5.2	-29.2	141	46.0	-3.3	-4.3				
42	67.6	49.7	-6.8	92	31.2	34.8	-28.9	142	63.3	-2.4	-5.6				
43	71.5	43.2	-7.2	93	69.6	43.8	-5.5	143	75.3	-1.4	-6.9				
44	73.3	35.5	-7.5	94	70.6	42.3	4.4	144	79.9	-0.4	-7.0				
45	77.0	29.0	-7.2	95	55.0	69.0	21.9	145	81.7	0.0	-6.1				
46	81.6	22.6	-7.0	96	69.8	37.7	20.4	146	28.0	-0.1	-0.1				
47	82.9	19.1	-6.5	97	65.3	40.2	45.0	147	48.8	-1.9	-3.0				
48	84.5	15.8	-6.5	98	67.3	1.0	33.2	148	67.9	-0.9	-5.1				
49	85.9	11.3	-5.9	99	59.6	-32.4	34.6	149	78.2	0.1	-6.4				
50	86.8	7.6	-6.0	100	69.4	-27.3	8.3	150	82.1	0.5	-5.7				

Appendix D19. Colorimetric Data Sheet for Sample No. 19 (Delta L* = +45).

ID	L*	a*	b*
1	64.9	-32.5	-40.8
2	58.1	69.7	-2.6
3	80.8	-0.8	76.8
4	27.1	13.5	-44.0
5	66.0	-45.3	14.9
6	56.0	67.0	39.7
7	38.2	-1.6	-0.9
8	43.0	9.3	-34.7
9	72.6	-33.3	11.7
10	68.4	44.2	27.5
11	65.9	5.9	-22.6
12	78.7	25.1	16.5
13	77.5	4.5	0.1
14	77.4	-17.6	8.0
15	77.1	4.1	-14.7
16	83.9	-6.5	2.5
17	82.5	12.1	6.2
18	18.9	-8.0	-7.1
19	18.6	4.2	-1.5
20	21.5	-3.5	3.1
21	7.6	-1.7	-4.8
22	17.7	-9.5	-1.1
23	16.5	2.0	-0.4
24	9.4	-1.6	-3.0
25	30.2	-0.6	0.3
26	90.2	2.0	-3.6
27	66.8	-31.3	-39.0
28	69.3	-28.4	-36.0
29	71.0	-25.4	-33.5
30	73.1	-22.9	-31.1
31	75.9	-20.2	-28.0
32	78.5	-16.5	-24.1
33	81.3	-12.4	-19.5
34	83.0	-9.9	-16.2
35	84.5	-6.9	-13.8
36	85.7	-4.7	-11.9
37	87.8	-2.9	-9.7
38	88.4	-1.1	-7.5
39	89.9	1.2	-4.7
40	61.6	63.1	-5.0
41	65.2	56.5	-5.8
42	68.0	49.3	-6.6
43	71.8	42.9	-7.1
44	73.7	34.3	-7.3
45	78.2	28.5	-7.0
46	83.1	21.5	-7.4
47	84.6	18.2	-7.0
48	85.4	14.1	-6.6
49	86.2	10.5	-6.2
50	87.8	7.5	-6.0

ID	L*	a*	b*
51	88.1	6.1	-5.6
52	89.3	3.5	-4.8
53	80.3	-0.9	69.6
54	79.8	-1.0	60.7
55	80.1	-0.9	49.5
56	80.5	-1.1	43.2
57	81.3	-0.7	34.3
58	82.5	-0.3	26.6
59	83.1	0.3	18.4
60	83.6	0.4	14.9
61	84.0	0.7	12.3
62	84.7	2.0	7.3
63	86.5	2.0	3.5
64	87.4	1.8	2.4
65	88.8	1.9	0.3
66	42.2	-2.1	-2.0
67	54.1	-1.9	-3.4
68	65.7	-0.7	-5.2
69	74.9	0.1	-5.0
70	79.8	1.1	-6.7
71	81.9	1.1	-5.9
72	83.0	1.1	-4.8
73	84.1	1.3	-5.6
74	84.9	1.5	-5.0
75	85.7	1.4	-4.4
76	87.2	1.6	-3.3
77	88.1	1.5	-3.6
78	88.8	2.0	-4.0
79	42.9	55.8	-27.3
80	49.1	59.5	-5.8
81	57.2	67.5	13.8
82	50.2	56.6	26.6
83	72.6	30.4	62.8
84	55.7	3.2	40.3
85	59.8	3.6	0.0
86	66.5	-24.7	54.4
87	56.5	-46.4	13.7
88	68.3	-37.5	-16.2
89	59.2	-41.4	-26.1
90	50.4	-24.4	-49.1
91	30.4	4.9	-29.8
92	32.2	35.4	-29.0
93	70.0	43.3	-5.6
94	71.5	41.0	4.5
95	56.2	68.3	21.0
96	70.5	37.2	20.4
97	67.0	39.4	42.7
98	67.9	1.1	34.1
99	61.2	-33.1	35.7
100	70.6	-28.5	9.1

ID	L*	a*	b*
101	67.6	-41.8	-2.2
102	72.4	-23.5	-23.4
103	38.3	-14.5	-35.9
104	48.6	7.6	-25.9
105	41.0	31.2	-6.1
106	71.6	32.3	-4.8
107	81.8	17.9	-2.9
108	43.0	29.5	11.1
109	79.6	15.4	7.8
110	43.5	1.6	19.1
111	59.4	2.1	19.1
112	72.2	2.2	11.8
113	82.2	3.9	-3.6
114	47.4	-27.4	7.8
115	66.8	-18.3	6.9
116	76.7	-6.6	2.4
117	49.1	-26.1	-12.3
118	72.3	6.1	-12.8
119	31.4	2.1	-16.5
120	80.6	-5.2	-10.1
121	72.5	-15.7	-15.0
122	10.0	-1.8	-3.0
123	17.0	-3.1	-2.8
124	25.9	-6.6	-3.2
125	13.5	-1.6	-2.3
126	25.9	-3.9	-1.5
127	35.9	-6.3	-2.8
128	43.5	-7.8	-3.5
129	18.0	-1.3	-1.3
130	32.6	-5.1	-2.2
131	44.4	-6.6	-3.3
132	56.0	-6.3	-3.8
133	66.6	-5.5	-6.3
134	22.3	-1.5	-1.2
135	40.9	-4.4	-3.3
136	55.5	-4.7	-4.9
137	68.9	-4.0	-6.2
138	78.6	-2.3	-7.9
139	80.7	-1.5	-6.6
140	27.7	-0.4	-0.4
141	47.7	-3.6	-3.4
142	66.0	-2.8	-5.7
143	78.3	-1.0	-6.9
144	81.6	-0.3	-6.3
145	83.9	-0.2	-6.1
146	29.7	0.2	-0.2
147	51.0	-2.6	-3.9
148	70.8	-0.7	-6.5
149	80.6	0.4	-6.6
150	83.5	0.6	-6.2

ID	L*	a*	b*
151	85.1	1.0	-5.0
152	43.7	-14.6	-7.9
153	59.4	-8.2	-6.3
154	75.2	-4.3	-7.1
155	81.3	-1.4	-6.8
156	85.0	0.1	-5.7
157	87.6	0.8	-4.6
158	88.3	1.5	-4.5
159	61.7	-35.9	-42.1
160	52.9	72.2	-5.0
161	67.6	-1.9	66.4
162	23.8	13.3	-36.4
163	60.8	-52.7	16.0
164	53.0	69.1	40.0
165	59.6	4.5	-20.9
166	73.1	-15.9	5.1
167	77.5	23.6	14.5
168	20.1	11.1	-29.6
169	50.9	-58.9	18.3
170	44.7	56.9	32.0
171	50.1	3.3	-19.1
172	70.9	-17.2	4.5
173	71.0	21.3	13.0
174	34.3	-29.9	-26.2
175	28.9	34.4	-4.2
176	41.2	-4.3	31.1
177	16.1	2.2	-12.1
178	40.0	-39.9	10.9
179	34.7	29.0	16.4
180	37.6	0.9	-15.2
181	51.4	-17.0	4.3
182	47.5	13.0	10.7

Appendix D20. Colorimetric Data Sheet for Sample No. 20 (Delta L* = +50).

ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*	ID	L*	a*	b*
1	65.7	-31.6	-40.5	51	88.9	5.5	-5.0	101	68.5	-40.0	-2.8	151	87.2	0.6	-5.0
2	58.6	67.3	-3.1	52	90.3	3.5	-3.8	102	73.8	-22.2	-24.3	152	45.0	-14.2	-8.1
3	80.5	-0.6	76.2	53	80.6	-1.1	69.5	103	38.4	-14.8	-36.6	153	61.8	-8.6	-7.2
4	27.4	13.7	-43.5	54	79.9	-0.8	58.5	104	49.4	8.5	-26.7	154	78.3	-3.1	-8.7
5	66.3	-44.1	14.0	55	79.9	-0.8	49.7	105	42.9	33.3	-7.3	155	83.3	-0.4	-7.2
6	56.2	66.6	39.4	56	80.3	-0.4	41.5	106	74.0	33.3	-4.7	156	86.6	0.4	-6.7
7	39.1	-0.8	-0.8	57	81.1	-0.8	34.8	107	83.7	18.6	-4.2	157	88.5	1.6	-5.5
8	43.4	9.4	-35.3	58	82.2	-0.2	26.8	108	44.4	30.4	9.9	158	89.3	1.8	-4.7
9	72.7	-32.4	11.2	59	83.3	0.4	18.4	109	80.8	16.4	8.5	159	62.6	-35.3	-41.7
10	67.9	45.3	26.7	60	83.8	0.2	14.8	110	43.4	1.4	19.3	160	54.3	71.2	-4.1
11	67.6	7.0	-23.9	61	84.1	0.7	11.7	111	60.5	2.4	19.1	161	67.7	-1.9	66.2
12	78.8	25.3	16.2	62	85.6	2.0	7.8	112	72.6	2.0	12.1	162	23.5	13.8	-37.4
13	79.8	5.2	-0.5	63	87.0	2.0	3.7	113	83.9	4.0	-2.7	163	62.7	-50.0	15.0
14	78.2	-17.1	7.4	64	88.1	2.0	2.4	114	48.9	-27.5	7.5	164	54.0	69.1	39.5
15	77.9	3.9	-15.0	65	89.5	1.9	0.7	115	69.2	-16.2	5.5	165	60.5	5.9	-22.3
16	84.5	-5.6	1.7	66	43.5	-1.6	-2.2	116	78.4	-5.5	2.0	166	74.8	-15.1	4.3
17	83.7	12.2	6.9	67	56.4	-1.0	-3.9	117	51.5	-27.0	-13.4	167	79.0	23.5	14.5
18	19.2	-8.4	-7.9	68	68.3	0.5	-5.1	118	73.6	5.6	-12.8	168	20.3	11.6	-29.6
19	18.6	5.4	-1.6	69	78.2	0.9	-6.3	119	32.0	3.1	-16.4	169	52.9	-57.8	17.9
20	21.9	-3.3	3.3	70	82.5	1.0	-5.5	120	82.5	-4.9	-11.7	170	46.0	59.4	33.2
21	8.5	-1.4	-4.8	71	83.8	1.3	-6.2	121	75.4	-14.8	-15.2	171	51.7	3.9	-19.0
22	18.7	-9.8	-0.9	72	85.2	1.4	-5.2	122	10.7	-1.4	-3.3	172	72.7	-17.2	4.1
23	17.5	2.7	-0.1	73	86.0	1.6	-4.7	123	17.3	-3.1	-2.4	173	73.9	22.2	12.6
24	10.4	-1.3	-2.8	74	86.3	1.4	-4.3	124	27.0	-6.8	-3.1	174	35.0	-30.8	-26.7
25	31.4	0.2	0.0	75	86.9	1.6	-3.7	125	14.1	-1.2	-2.5	175	29.3	36.2	-5.2
26	90.5	1.9	-2.9	76	88.3	1.9	-4.2	126	26.7	-4.2	-1.1	176	41.5	-4.5	31.3
27	67.8	-29.9	-38.1	77	89.1	2.0	-4.2	127	37.1	-6.1	-3.4	177	16.3	2.5	-12.4
28	69.7	-26.6	-35.0	78	89.9	2.1	-3.8	128	45.4	-6.7	-4.0	178	40.8	-41.9	10.9
29	71.4	-25.4	-33.4	79	44.5	55.0	-27.4	129	18.1	-1.2	-1.6	179	35.0	31.2	16.9
30	73.2	-22.1	-30.7	80	51.1	59.4	-7.7	130	34.0	-4.5	-2.2	180	39.0	2.3	-15.2
31	75.9	-19.7	-27.6	81	57.0	68.1	14.3	131	45.8	-6.3	-4.0	181	53.6	-18.2	4.7
32	78.9	-16.0	-23.7	82	52.1	57.5	26.1	132	58.5	-5.7	-5.0	182	48.8	12.8	10.4
33	81.8	-12.3	-19.5	83	72.6	30.7	62.9	133	69.9	-4.2	-7.0				
34	83.6	-10.0	-16.8	84	56.3	4.0	42.5	134	24.2	-1.0	-1.5				
35	85.0	-6.9	-14.4	85	61.5	4.6	-1.2	135	41.5	-5.3	-3.4				
36	86.2	-4.4	-11.5	86	67.0	-24.3	53.2	136	57.3	-5.0	-5.2				
37	88.5	-2.8	-9.5	87	58.6	-45.4	13.4	137	71.8	-3.5	-7.1				
38	89.6	-0.8	-7.8	88	67.5	-38.5	-16.3	138	81.3	-1.8	-6.6				
39	90.4	1.5	-5.4	89	61.9	-38.7	-26.7	139	82.8	-1.2	-7.5				
40	61.4	62.8	-5.2	90	51.1	-24.6	-49.5	140	28.7	-1.0	-0.9				
41	64.5	56.5	-6.0	91	30.3	5.4	-30.0	141	49.9	-2.8	-4.0				
42	67.9	49.6	-6.6	92	33.4	36.1	-29.5	142	68.6	-1.6	-7.4				
43	72.0	42.2	-6.5	93	70.9	42.4	-5.8	143	80.9	-0.5	-6.8				
44	73.7	34.6	-7.4	94	72.4	40.9	4.9	144	83.6	-0.2	-6.7				
45	78.4	27.5	-8.0	95	57.4	66.5	19.4	145	85.3	0.4	-5.5				
46	84.2	19.7	-7.2	96	71.2	38.7	21.2	146	30.5	0.2	-1.0				
47	85.2	16.6	-7.2	97	67.7	39.5	42.1	147	53.8	-1.6	-4.0				
48	86.4	13.5	-7.0	98	68.4	0.9	34.0	148	73.6	-0.6	-5.7				
49	87.4	10.4	-6.9	99	62.6	-32.5	34.9	149	82.8	0.5	-6.4				
50	88.5	7.4	-5.5	100	72.0	-27.5	9.3	150	85.4	0.8	-5.0				

Appendix E. Set of instructions to be presented to each observer
(Based on "RIT Research Corporation, "Psychometrics," Lab Experiment 4).

Instructions

I want you to help me to build a visual scale based on the color differences between images or samples. I will give you three sets of similar samples. I want you to select one sample from each set and place it between the other two images.

Your participation will be in three steps shown below. There is one set of samples in each step. Each set of samples contains five images. You may take as much time as you like to choose the image of your preference from each set, until I consider you may be exhausted. If you cannot choose one image between two that look equal to you, choose one of that pair at random.

The steps to follow are:

Step 1. I will give you the set of samples No. 1 and the ends of the visual scale. The ends are two images. These images will be placed on a special board separated with enough space between them to place the image or sample of your preference. Choose one sample from the set of samples given, and place it between the ends of the partial visual scale. Your selection must be based on the image you chose having the same color difference to one end as to the other end. Give me the other four samples from the set, and wait until I record the data related to your selection.

Step 2. I will give you the set of samples No. 2 and one end of the visual scale and the image that you selected before. These images will be placed on a special board separated with enough space between them to place the image or sample of your preference. Choose one sample from the set of samples given, and place it between the ends of the partial visual scale. Your selection must be based on the image you chose having the same color difference to one end as to the other end. Give me the other four samples from the set, and wait until I record the data related to your selection.

Step 3. I will give you the set of samples No. 3 and one end of the visual scale and the first image that you selected. These images will be placed on a special board separated with enough space between them to place the image or sample of your preference. Choose one sample from the set of samples given, and place it between the ends of the partial visual scale. Your selection must be based on the image you chose having the same color difference to one end as to the other end. Give me the other four samples from the set, and wait until I record the data related to your selection.

Once I gather all the data related to your participation in the building of the visual scale based on the color differences between images, you participation will be done.

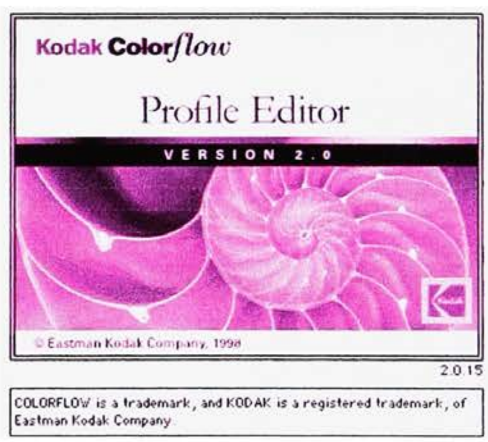
Thank you very much for your participation!

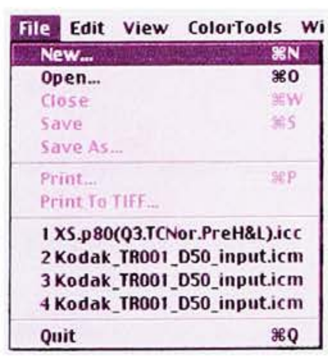
Appendix F. Generation of Kodak Color*flow* Medium-Size Target TIFF File.

"The KODAK COLORFLOW Profile Editor is a complete set of Color Management System tools for building, evaluating, and tuning ICC-compliant color profiles."[1] The Profile Editor is one of the solutions to color reproduction. With this profiling software it is possible to build ICC-based CMS device profiles for monitor, input, and output devices.

Before a profile can be built, the test target TIFF file must be generated. The Kodak Color*flow* Profile Editor has a target to build profiles, and the process is as follows.

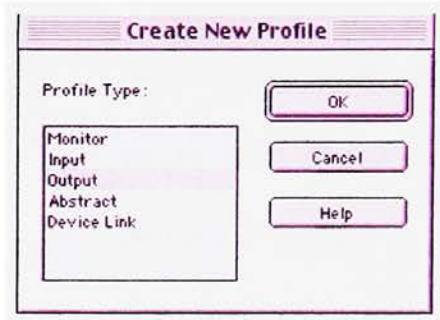
1. Launch Kodak Colorflow Profile Editor. A display with the logo of the Kodak Colorflow Profile Editor will appear, as shown at the right.





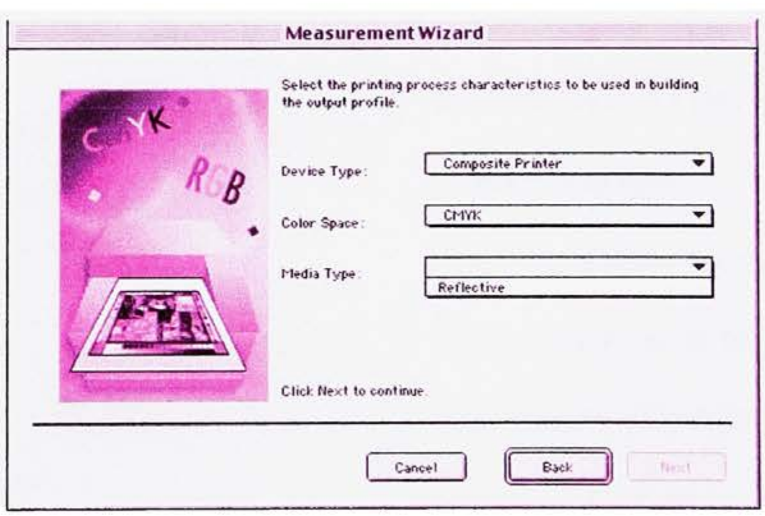
2. Select **New** from the **File** menu to start the process, as shown at the left. A dialog box, named **Create New Profile** will appear, as shown below.

3. Once the **Create New Profile** dialog box appears, the Output Profile must be selected, as highlighted in the figure at the right.



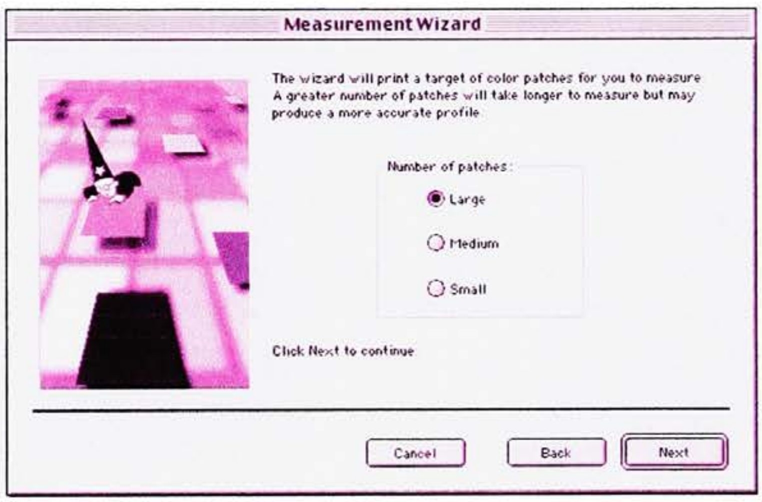
4. The **Measurement Wizard** will appear. Click **Next** to reach the printing process characteristics prompt where the device type, the color space and the media type are asked.

5. In the printing process characteristics prompt, as shown at the right, select the **Composite Printer** as Device Type, **CMYK** as Color Space and **Reflective** as Media Type.



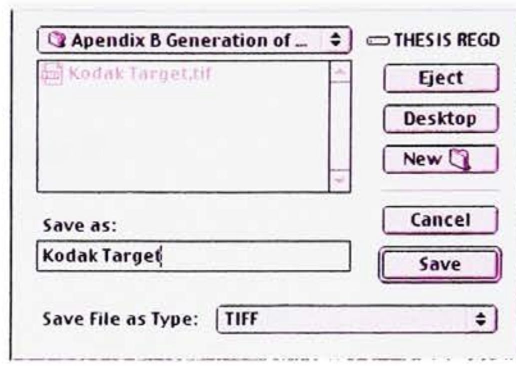
6. Next, the **Measurement Device** must be selected. In this case, the device to be used is **Gretag Spectrolino / SpectroScan**.

Once the measurement device has been selected, the target size must be chosen. To build a profile a medium size target will be used. Then, select the **Number of Patches** as **Medium**.



7. Select the option **Print to TIFF**, and click **Print**. The Profile Editor will start to generate the large-number-of-patches target as a TIFF file.

8. Select the desired setting for the TIFF file when the **Save File** prompt appears. The Kodak Color*flow* Target TIFF file is generated once the **Save** button is clicked.



Endnotes of Appendix F

1. Kodak Colorflow™ Profile Editor. User's Guide & Reference. Version 2.0. Eastman Kodak Company, 1998. Document # 301-107869-001.

Appendix G. Generation of Kodak Color*flow* Profile.

With Profile Editor it is possible to build ICC-based CMS device profiles for output devices as follows: To build an output profile two actions are required before starting to build an output profile:

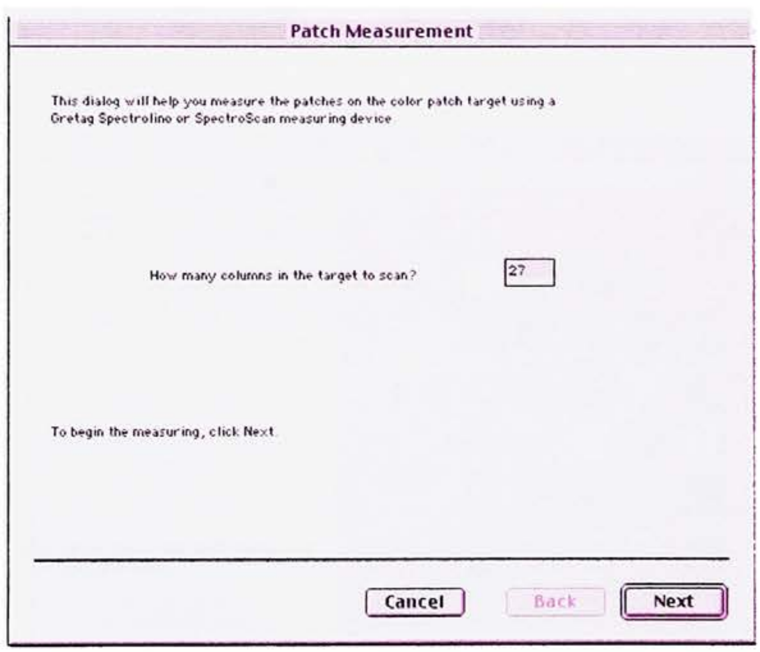
1. Have the target already printed (from the TIFF file as shown in the Appendix F) on the desired substrate.
2. Turn on the GretagMacbeth SpectroLino/SpectroScan before lunching Kodak Color*flow* Profile Editor software. The software will check that the measurement device is on-line.

Repeat the first seven steps described in Appendix F: Generation of Kodak Color*flow* Medium-Size Target TIFF File, and be sure the option **Print to TIFF** in step number 8 is unmarked (do not click to **Print**), the Profile Editor will generate the output profile in the next steps. The step numbers have been selected to keep the sequence given in Appendix F.

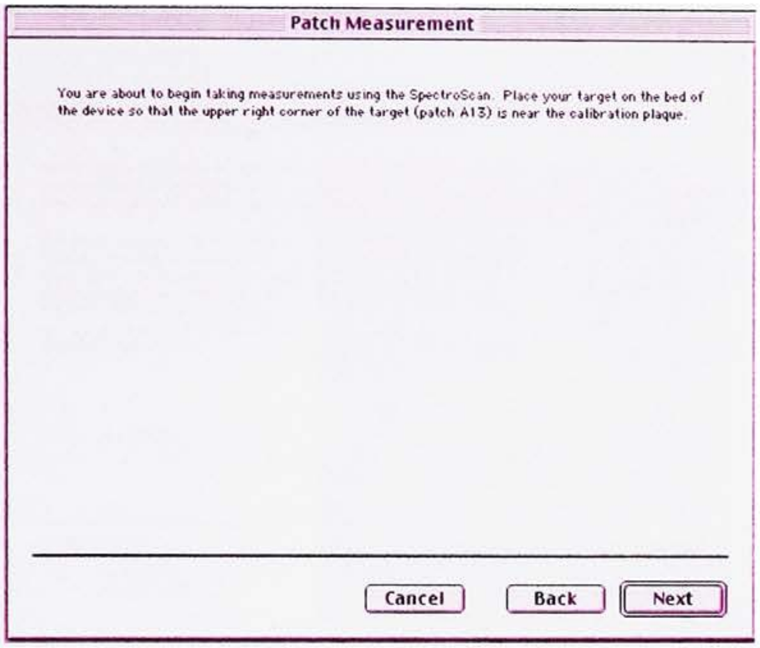
8. Do not select the option **Print to TIFF** in the "Measurement Wizard." Click **Next**.

9. In the next display click **New measurements**, and **Save resulting measurements in file** to keep the measurements for future applications. Then, click the **Measure…** button to continue, and the “Patch Measurement” window will appear as shown bellow.

10. Once the “Patch Measurement” window is displayed, type the right number of columns in the target that is being used. The large size target has **27** columns (for 928 colored patches), the medium size has **18** columns (for 445 colored patches), and the small target has **13** columns (for 226 colored patches). Then, verify the position of the target. The patch “A1” should be positioned in the bottom left corner of the device’s bed. Click **Next**.

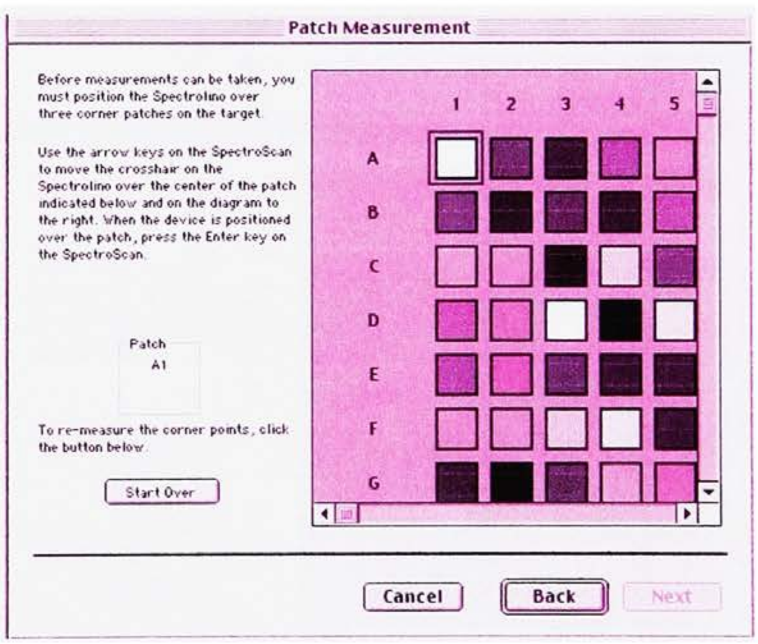


11. The Profile Editor software will check that the measurement device is on-line and is



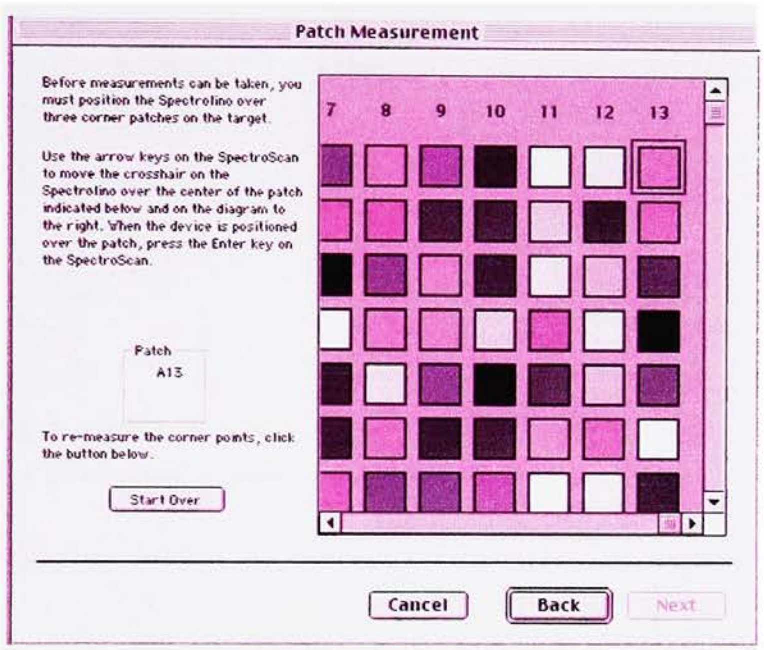
working properly. Sending a signal to the device, the software will activate the measurement device. After this, a window announcing SpectroScan is ready to start will ask for placing the target on the bed of the device. Click **Next**.

12. The “Patch Measurement” wizard will ask to place the target on the bed of the measurement device and position SpectroLino over three patches of the target. The first patch to position will be the patch called “A1” as shown at the right.

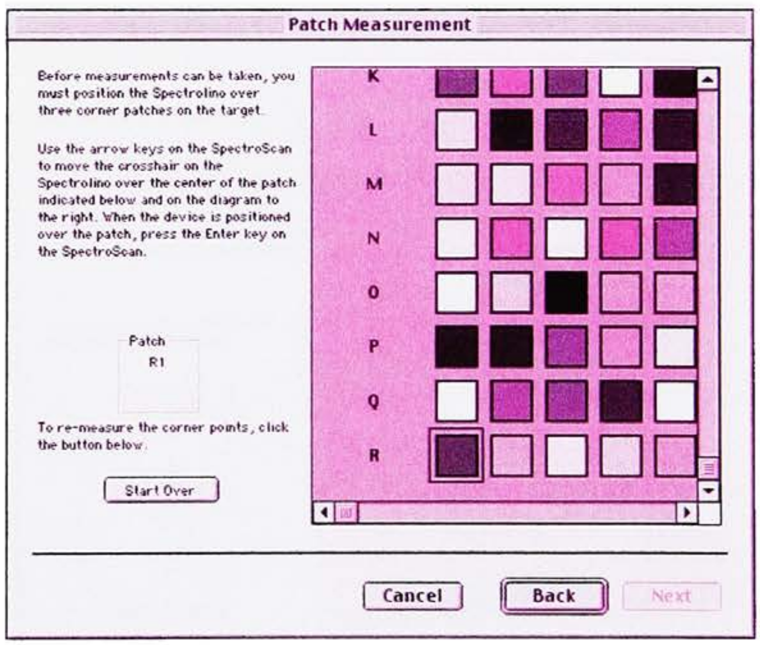


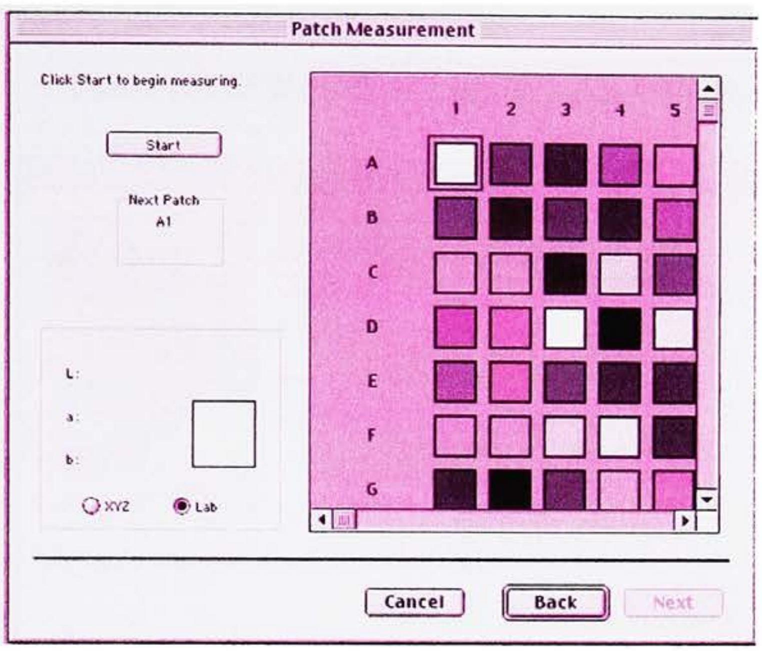
Once the device is positioned over this patch, click **Next** or push the **Enter** button on the measurement device (GretagMacbeth SpectroLino/SpectroChart has an **Enter** button at the right of the positioning key pad).

13. The "Patch Measurement" wizard will ask for positioning of the next patch. The second will be the patch called "A13" if the target is the small-size target, "A18" if the target is the medium-size target, or "A27" if the target is the large-size target. Once the device is positioned over this patch, click **Next** or push the **Enter** button on the measurement device.

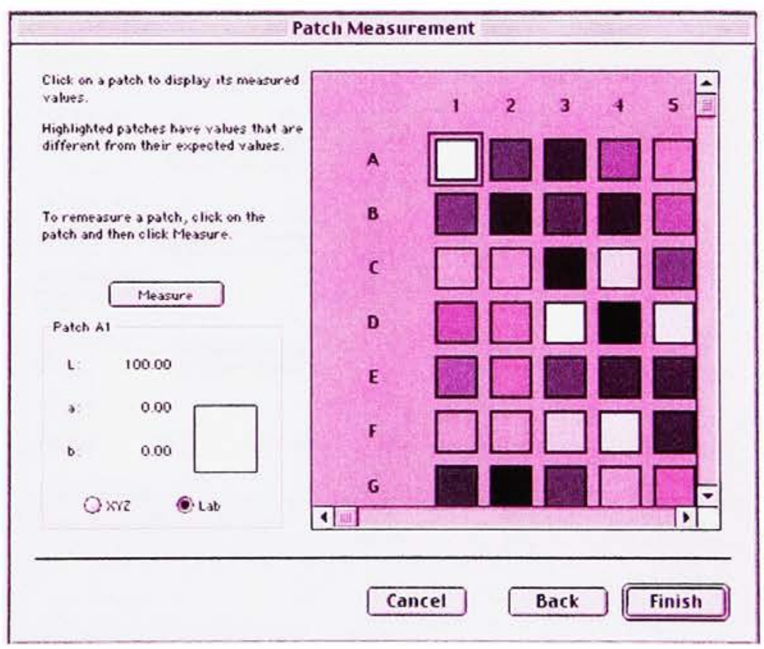


14. The "Patch Measurement" wizard will ask for positioning the next patch. The third patch will be the patch called "R1" if the target is the small-size target, "Y1" if the target is the medium-size target, or "AI1" if the target is the large-size target. Once the device is positioned over this patch, click **Next** or push the **Enter** button on the measurement device.



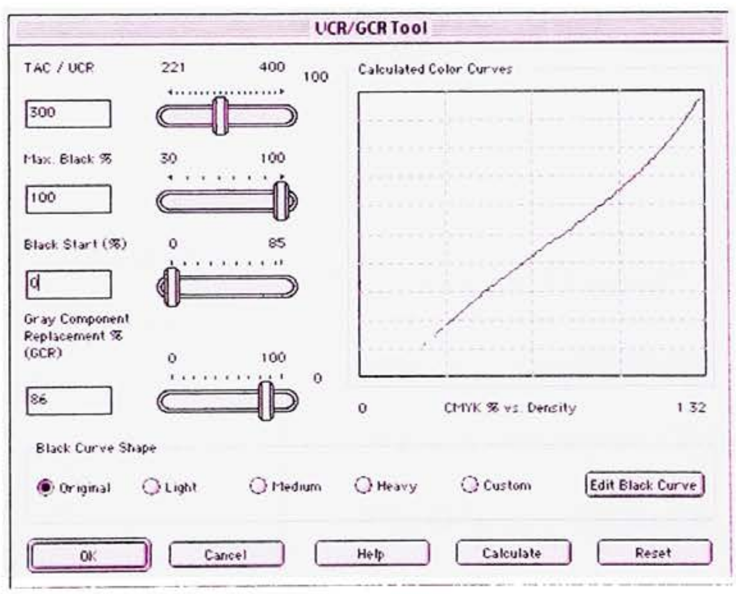


15. Once the patches are positioned as requested by the "Patch Measurement" wizard, the next display will appear. Select the desired kind of values to measured on the left side. There are two options to measure: **XYZ** option and **Lab** option. The first one measures and computes tristimulus coordinates (X, Y, Z) and the second the CIE color space values L*/a*/b*. It is a common practice in digital proofing to select the **Lab** method. Click **Start** at the upper left button to begin measuring.

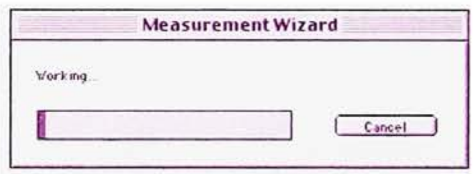


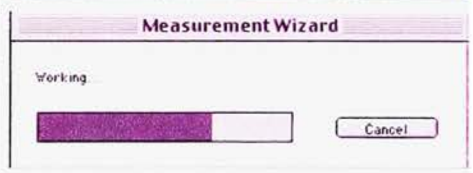
16. Just after start measuring, the Profile Editor will display the values for each patch being measured, as in the case shown at the right, for "A1" with values of L*=100.00, a*=0.00, and b*=0.00.

17. Once the Kodak Colorflow Profile Editor ends measuring, click **Finish**. The "Measurement Wizard" will appear again. Now the option sets the attributes for CMYK profile. Click **CMYK Options** if a CMYK setting is needed or the profile needs be modified. Otherwise click **Next**. For a deeper explanation on CMYK attributes, see Chan's thesis: "A Study of Matching the Color of EPSON Stylus COLOR 3000 to ANSI CGATS TR 001-1995 – Type 1 Printing." Anyway, the values associated with the CMYK output profiling for Composite CMYK with reflective substrate described by Kodak Colorflow Profile Editor User's Guide & Reference are shown at the right and written as: TAC/UCR = 300; Max. Black % = 100; Black Start % = 0; and Gray Component Replacement % (GCR) = 86.



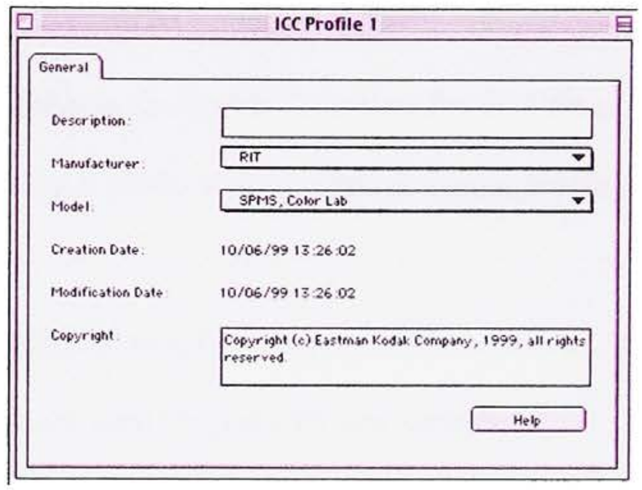
18. Next, the wizard will show that it has all the necessary information to build the output profile. Click **Build**. The "Measurement Wizard" will display the Working bar showing the advance, as illustrated in the next two images. The bar is advancing until the profiling work is done. The more patches used in the target, the more time required to complete the building task. There is a **Cancel** option if the process needs to be canceled.

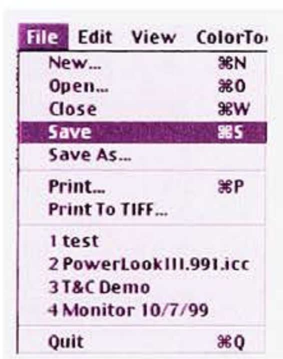




19. Once the profiling work is done, a Congratulations! Window will appear. Click **Finish** to save the profile.

20. The profile saving process has a window called "ICC Profile". Edit the desired **Description** for the profile, select the **Manufacturer** and the **Model**. It is recommended to keep the profile description equal to the name of the profile that will be saved later. Then, copy the description for future use.





21. Select **File/Save** from the menu to continue. Save the profile with the same name as the description edited in the step before. To use this profile it must to be saved in the **System Folder/ColorSync Profiles** folder for Macintosh computer. For PC computers, the profile must be saved in **Windows/System/Color** folder.

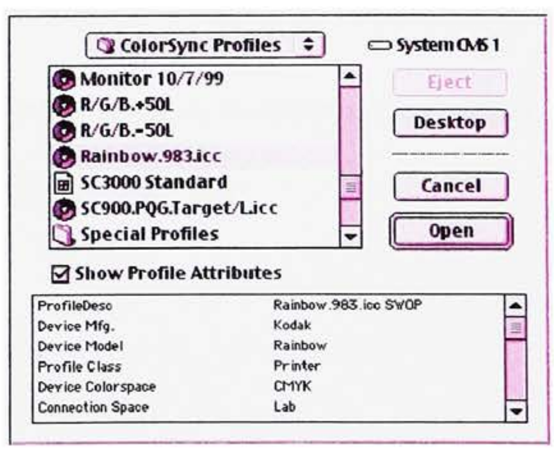
Appendix H. Creation of different Lightness Values.

With Profile Editor it is possible to tune ICC-based CMS device profiles for output devices using one of the three variables available in the Kodak Color*flow* Profile Editor color tools (lightness, Saturation, Hue). Tuning a profile requires that an output profile has already been built.

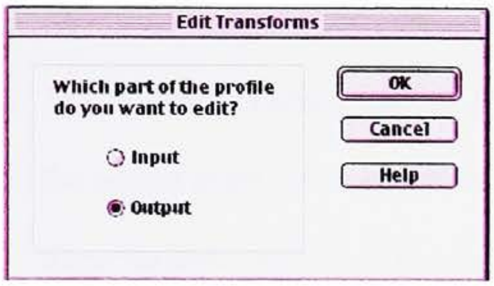
In this research, with an output profile built, as shown in Chapter 5: Methodology, the Kodak Color*flow* Profile Editor Color Tools are used varying only one variable: *Lightness*. The procedure to create the different proof profiles with different lightness values is as follows.

1. Once the Kodak Color*flow* Profile Editor has been lunched, select **File/Open** from the menu to open the profile that will be tuned to generate the proof profiles.

2. Select the desired profile by highlighting it from the **System Folder/ColorSync Profiles** folder list for Macintosh computer, or from **Windows/System/Color** folder list for a PC computer.

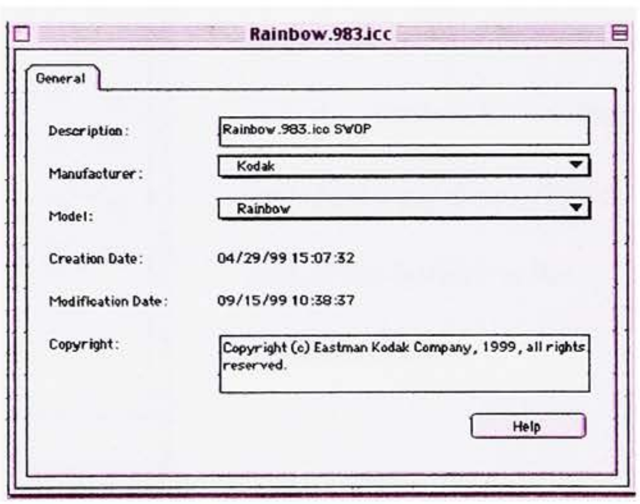


Once the desired profile had been selected, the profile attributes are able to be seen when clicking the **Show Profile Attributes** box. Click **Open**.



3. The "Edit Transforms" window will be open. Select the desired part of the profile to be tuned (modified). In this particular case, the output part of the profile will be tuned. Click **OK**.

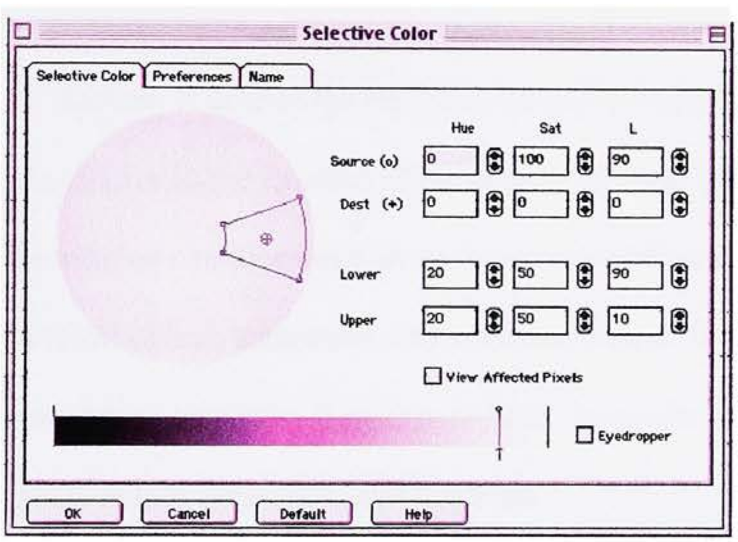
4. The "ICC profile" window will be displayed showing the profile attributes as **Description**, **Manufacturer**, and **Model**. Keep this window open during the tuning process.



5. Select **View/Image** from the menu, to observe the changes while tuning the selected profile.

6. Select **ColorTools/Selective Color** from the menu to start the process. The "Selective Color" window will appear as shown below.

7. The "Selective Color" window shows the **Hue**, **Saturation**, and **Lightness** values for the source point and the destination point, and lower and upper end of each of the three variables ranges, as shown at the left. The color wheel at the left side of the window represents the color space being used; at the right side the displays for attributes and their ranges are placed; and at the bottom is the **Lightness** bar.



As defined in the Color*flow* V2.0 Manual, for the **Selective Color** option, the color wheel is the color circle at the upper left area of the Selective Color display that represents the colors that can be applied to a image. The circumference of the circle represents **hue**. The radius represents **saturation**, where the closer to the circumferences a color is, the more saturated it is. **Lightness** is not represented on the color wheel.

Color range box. It is the squarish, pie-shaped box within the color wheel that determines the area in which the color shift between the source and destination occurs. The numbers for Hue, Sat, and L under Upper and Lower determine the boundaries. Both source and destination must be within the boundaries.

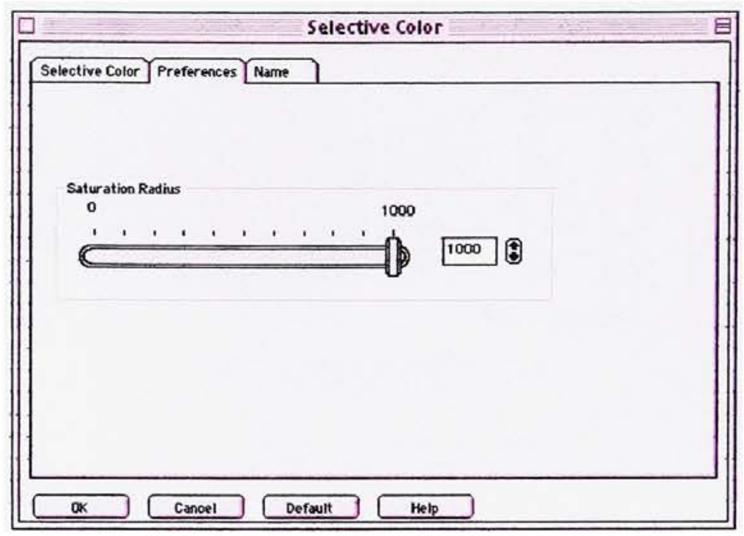
Source. Indicated by "o" on the color wheel, represents the original color of a point in the image in terms of a hue, saturation, and lightness. Source values are absolute. **Destination**. Indicated by "+" on the color wheel, represents the color to which the sources (o) shifts. Destination values are relative to the source values.

Lower. It defines the region of the color range box in terms of Hue, Sat, and L, and are relative to the location of the source. In other words, it represents the color range box boundaries counterclockwise to the source and closest to the color wheel circumference in terms of hue, saturation, and lightness. **Upper**. Represents the color range box boundaries clockwise (upper region) to the source and closest to the color wheel center in terms of hue, saturation, and lightness.

Hue. Represents hue for source, upper, and lower. **Sat**. Represents saturation for source, upper, and lower. **L**. Represents lightness for source, upper, and lower. **Lightness slider**. Defines the lightness level of the selected color range.

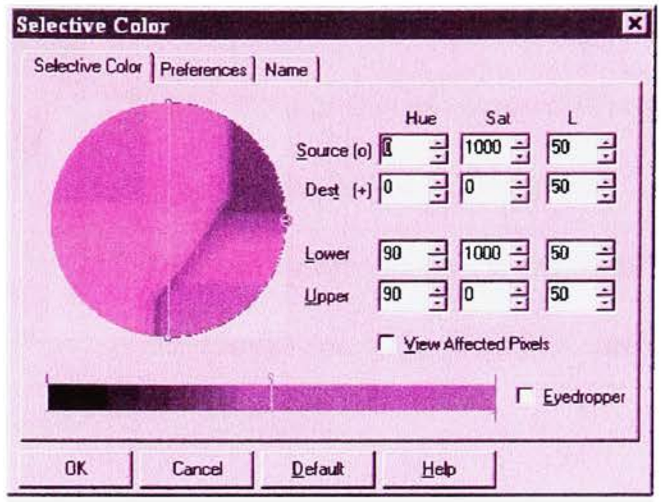
In the **Preferences** option, the **Saturation radius slider** is used to select how much of a color space is displayed in the color wheel. **Text box**. Numerically represents how much of a color space is displayed. A setting of 1000 includes all colors. A setting of 0 displays only colors that are close to neutral.

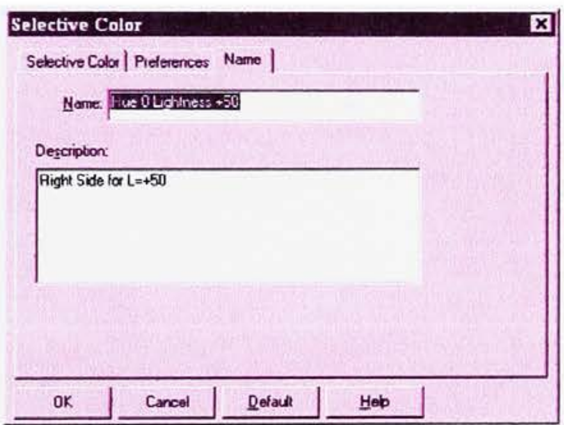
Saturation radius must be set before setting the color range box, because the saturation radius can affect the shape of the color range box. In the **Name** option, name is used to record the device profile modification. Under **Description**, a brief description of the modification can be entered. The name is displayed in the Edit List under Tool Name.



The technique in this research is using the selective color in two different areas (two area of the color wheel) with center points given by **Hue** and **Saturation** as two color center points with hue values equal to 0, and 180 degrees, with +/- 90 degrees to build each **Hue** range and to cover all the color wheel; the two color center points with the same **Saturation** value equal to 500 units. The **Lightness** was changed by five units for each proof profile to build twenty one different output profiles (included 0 that matched with the reference). Starting with **Lightness** value equal to 50, as a source, the destination **Lightness** values will be: -50, -45, -40, -35, -30, -25, -20, -15, -10, -5, 0, +5, +10, +15, +20, +25, +30, +35, +40, +45, and +50 units.

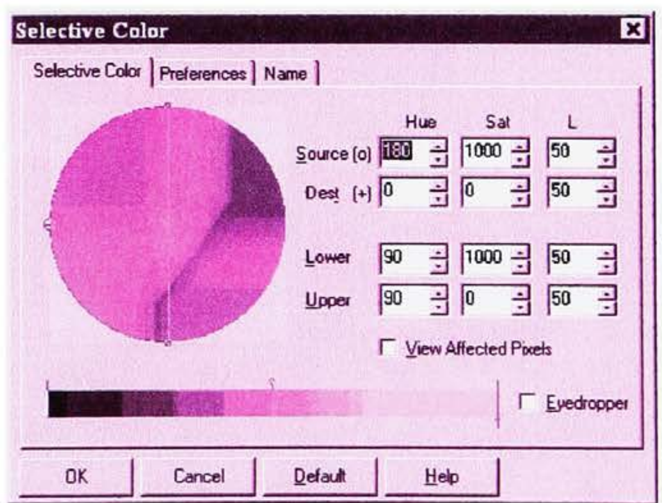
As shown at the right, the first area has to be set with Hue equal to 0, Sat equal to 1000, and L equal to 50 for the source, and Hue equal to 0, Sat equal to 0, and L equal to 50 for the Dest. Over the lightness slider, both the arrow at the right end, and the small circle (source) in the center, can be seen.

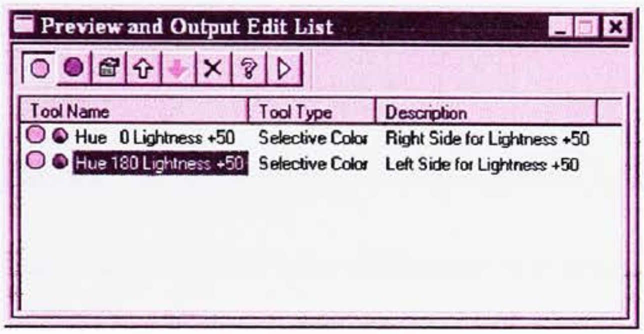




In the figure at the left, the assigned Name and its Description for this modification is shown.

The setting for the second area is shown at the right, with Hue equal to 180, Sat equal to 1000, and L equal to 50 for the source, and Hue equal to 0, Sat equal to 0, and L equal to 50 for the Dest.





With the two areas of modification, the first proof profile of twenty different profiles was built. The next step is to **Save** those modifications. At any stage of this modification, the **Edit List** can be viewed as shown in the **Preview and Output Edit List** display.

Once the tuned proof profile had been saved, the process of modification was repeated for two areas of the color wheel, for the other nineteen proof profiles.

Appendix I. Evaluation of Scales.

The color difference ΔE^*_{ab} is a comparison between a single color and its reference. The mathematics of this color difference in terms of the CIELAB is called CIE 1976. The color difference formula follows:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where the particular differences are:

in lightness	$\Delta L^* = L^*_{sample} - L^*_{reference}$,
in a* coordinate	$\Delta a^* = a^*_{sample} - a^*_{reference}$,
in b* coordinate	$\Delta b^* = b^*_{sample} - b^*_{reference}$

Evaluating the differences for lightness, a*-coordinate, and b*-coordinate, for each colorimetric data sheet, the calculation of the color difference is shown in the next tables. The first column represents the IT8.7/3 patch ID, and the columns represent each one of the samples with their own lightness value. Their three-dimensional representation are shown in the graphs that follow, and are arranged as the IT8.7/3 basic target.

Color difference calculation for lower lightness range, and ID from 1 to 40

ID	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
1	26.26	24.48	22.20	18.78	16.27	12.73	10.42	7.10	4.78	2.79	0.00
2	57.46	51.63	45.63	42.04	37.42	32.63	28.18	22.32	15.22	9.02	0.00
3	2.16	2.62	2.07	2.70	1.95	1.54	1.16	1.49	2.05	0.81	0.00
4	2.06	3.16	3.43	2.59	1.94	1.37	1.15	1.03	0.95	0.67	0.00
5	37.33	31.79	27.39	23.31	20.22	15.98	12.87	8.39	6.05	3.11	0.00
6	57.85	50.95	46.06	41.75	35.91	31.45	26.09	20.42	14.66	8.48	0.00
7	18.22	17.54	15.84	13.22	11.21	9.24	7.30	5.49	3.90	2.05	0.00
8	5.46	5.95	4.98	4.33	3.68	3.02	3.11	1.53	1.57	1.13	0.00
9	20.30	18.50	17.02	15.45	13.71	11.69	9.37	6.98	4.82	2.71	0.00
10	32.45	28.36	23.85	20.82	18.04	14.16	12.24	8.78	6.59	3.16	0.00
11	13.48	13.14	11.84	9.99	8.74	7.54	6.16	3.95	2.71	1.65	0.00
12	22.05	20.69	18.91	16.49	13.79	11.73	9.27	7.24	4.68	2.46	0.00
13	23.37	22.26	19.12	16.55	14.35	12.30	9.71	7.78	5.29	2.61	0.00
14	16.61	15.20	13.12	11.62	9.86	8.33	6.48	4.69	3.22	2.58	0.00
15	12.69	11.50	10.22	9.54	8.10	6.35	5.44	4.21	2.75	1.46	0.00
16	12.95	11.84	10.42	9.20	7.81	6.35	5.03	3.50	2.51	0.82	0.00
17	13.72	13.09	11.95	10.68	8.92	7.66	6.21	5.13	4.90	2.52	0.00
18	5.46	5.89	5.82	5.20	4.30	4.20	3.17	2.51	1.41	1.12	0.00
19	5.31	6.12	5.70	5.38	5.22	3.85	4.05	3.25	2.63	1.36	0.00
20	6.50	6.64	6.09	5.00	4.82	4.67	3.14	2.10	2.24	1.10	0.00
21	1.12	2.43	2.63	2.30	2.35	1.81	1.87	1.23	0.84	0.75	0.00
22	5.44	5.85	5.70	5.40	4.97	4.39	4.01	3.38	2.48	1.32	0.00
23	3.87	4.71	4.38	4.31	4.07	3.60	2.88	1.94	1.70	0.34	0.00
24	0.91	1.78	1.66	1.58	1.44	1.24	0.92	0.96	0.30	0.19	0.00
25	12.46	12.45	11.83	10.86	9.17	8.14	6.23	3.72	2.91	1.90	0.00
26	6.94	5.96	5.34	4.42	3.83	3.27	2.76	2.09	1.83	0.89	0.00
27	24.74	23.20	21.22	18.31	15.40	12.35	10.02	7.40	4.20	2.52	0.00
28	22.97	21.68	19.65	17.35	14.32	11.78	9.52	7.51	4.84	2.75	0.00
29	21.26	19.98	17.64	16.09	12.90	10.88	8.35	6.92	4.59	2.39	0.00
30	20.02	18.70	16.18	14.87	12.35	10.15	8.47	6.19	4.84	2.07	0.00
31	18.37	16.46	14.34	13.05	11.25	9.06	7.49	5.39	3.79	2.12	0.00
32	16.76	15.45	13.29	12.01	10.34	7.88	6.90	5.41	3.68	2.23	0.00
33	14.92	13.69	11.90	10.38	8.96	7.54	5.70	4.62	2.84	1.56	0.00
34	14.18	12.75	11.20	9.75	8.27	6.90	5.92	4.32	2.34	1.45	0.00
35	13.32	11.78	10.12	8.79	7.92	6.17	5.51	3.80	1.97	0.75	0.00
36	12.34	10.69	9.42	8.00	6.78	5.77	5.13	3.32	2.22	0.68	0.00
37	11.19	10.12	8.72	7.69	6.51	5.58	4.42	3.00	1.94	1.18	0.00
38	10.53	9.25	8.11	7.00	6.07	4.82	3.92	2.44	1.72	1.12	0.00
39	8.63	7.87	6.77	5.36	4.82	3.63	3.11	1.99	1.30	0.47	0.00
40	52.22	46.13	40.72	36.41	31.07	26.52	22.49	15.89	10.26	4.98	0.00

Color difference calculation for higher lightness range, and ID from 1 to 40

ID	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
1	2.37	3.57	6.13	7.85	10.19	11.58	13.20	15.29	16.10	17.20
2	4.05	8.23	9.79	11.00	11.69	12.94	13.87	15.40	15.81	16.30
3	2.33	1.76	2.31	3.10	1.05	0.49	1.13	0.94	1.24	1.43
4	0.50	1.49	1.08	0.61	0.51	0.81	0.73	1.16	1.54	1.43
5	2.27	3.76	6.06	9.11	11.73	14.87	17.54	21.87	23.21	24.39
6	3.00	7.07	10.97	12.46	14.00	12.79	13.49	12.76	12.60	12.48
7	2.49	4.13	4.65	7.34	8.56	9.86	10.59	12.45	14.00	14.88
8	0.88	1.81	0.96	1.38	1.50	3.07	3.05	4.45	4.78	5.43
9	2.98	4.30	6.53	8.91	10.96	12.13	13.51	15.98	16.85	17.15
10	2.97	6.50	8.20	11.27	12.64	14.19	15.14	15.86	16.22	15.97
11	1.48	1.68	3.15	4.75	5.88	6.69	7.70	9.52	10.45	12.41
12	2.11	4.00	5.37	7.62	9.62	11.25	12.05	13.33	14.40	14.44
13	3.22	5.04	7.49	11.22	13.64	16.49	19.09	22.70	24.93	27.28
14	1.68	2.59	3.59	6.09	6.77	8.26	9.12	10.39	11.09	11.79
15	0.78	1.82	2.22	3.69	4.49	5.98	6.72	7.78	8.52	9.41
16	1.31	2.34	3.58	4.77	5.79	7.01	7.72	9.11	9.75	10.44
17	2.01	3.80	3.67	5.43	5.99	6.82	8.23	8.56	8.99	10.26
18	0.93	0.63	1.95	3.22	4.66	5.28	7.63	8.87	9.69	10.29
19	0.14	1.51	1.97	3.68	4.41	6.27	7.60	8.20	10.61	11.18
20	1.17	1.51	1.56	3.37	2.80	4.44	5.64	6.86	7.74	8.11
21	0.30	0.36	0.17	0.78	0.70	1.33	1.55	1.60	1.51	2.25
22	1.25	0.81	2.24	3.45	5.04	5.65	8.21	9.70	10.51	11.58
23	0.61	1.08	1.82	3.48	4.36	5.43	6.77	8.40	9.48	10.74
24	0.51	0.79	1.26	1.49	2.22	2.56	2.84	3.95	4.38	5.27
25	2.01	2.47	4.07	5.61	6.71	8.84	9.39	11.62	12.65	13.87
26	0.16	1.06	1.46	2.68	3.48	4.38	4.80	5.79	6.71	6.98
27	2.13	3.85	6.35	8.41	10.40	11.80	12.93	15.51	15.79	17.40
28	2.21	3.54	6.33	8.00	9.60	11.17	12.69	15.02	15.56	16.96
29	2.07	3.51	5.00	6.81	9.24	10.42	11.46	12.57	13.73	14.10
30	1.15	2.43	3.77	6.01	7.32	8.81	10.07	10.86	11.86	12.19
31	1.67	2.06	3.72	5.81	7.12	8.31	9.56	10.77	11.61	11.59
32	1.34	2.11	3.59	5.69	6.68	8.27	8.98	10.33	11.28	11.61
33	1.19	1.94	3.66	5.48	6.45	7.92	8.95	10.38	10.64	11.13
34	1.46	2.20	3.28	5.23	6.54	7.81	8.49	9.39	10.48	11.14
35	1.54	2.25	3.43	5.03	5.98	7.14	7.98	8.71	9.83	10.43
36	1.62	2.47	3.23	4.56	5.71	6.62	7.42	8.89	8.95	9.44
37	1.37	2.37	3.01	4.37	5.04	5.59	6.88	7.58	8.62	9.35
38	1.01	1.73	2.54	3.62	4.64	5.69	6.42	7.33	7.97	9.20
39	0.93	1.71	2.26	3.16	4.30	5.20	5.58	6.87	7.91	8.40
40	3.24	5.99	9.06	11.40	12.72	14.06	15.40	16.54	16.96	16.75

Color difference calculation for lower lightness range, and ID from 41 to 80

ID	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
41	43.54	38.59	34.39	29.75	26.56	22.97	19.18	14.14	9.66	5.07	0.00
42	31.96	30.87	27.94	25.28	21.84	18.55	14.96	10.62	7.18	3.95	0.00
43	28.40	28.28	25.63	23.17	20.08	17.30	13.88	10.13	6.76	3.69	0.00
44	26.52	24.95	22.55	19.93	17.17	14.76	11.62	8.73	6.01	4.19	0.00
45	24.17	23.23	20.42	17.79	15.13	12.12	10.13	7.70	5.38	3.34	0.00
46	21.26	19.33	17.38	15.28	12.50	10.37	8.42	6.06	4.29	1.90	0.00
47	19.42	17.70	15.69	13.65	11.05	9.63	7.74	5.20	3.78	1.79	0.00
48	17.47	15.26	13.46	11.45	10.20	8.48	6.88	4.59	2.86	1.18	0.00
49	15.08	13.39	11.78	10.26	8.87	7.33	5.73	4.02	2.98	1.37	0.00
50	12.79	12.00	10.44	8.61	7.40	6.65	5.03	4.03	2.75	2.00	0.00
51	11.51	10.09	8.80	7.77	6.80	5.68	4.78	2.87	2.36	1.21	0.00
52	8.57	7.85	7.09	5.94	4.72	4.36	3.03	2.32	1.40	0.69	0.00
53	2.91	3.21	2.55	2.42	1.81	1.48	1.51	0.87	1.49	0.56	0.00
54	2.80	2.51	2.47	2.40	2.67	1.88	1.36	1.78	0.79	0.97	0.00
55	2.93	2.82	2.19	2.96	2.25	1.67	1.24	1.24	2.27	0.32	0.00
56	3.62	3.10	2.81	2.67	1.93	1.69	1.77	1.17	1.03	2.23	0.00
57	3.58	3.35	3.01	2.38	2.38	2.06	1.82	1.11	1.51	0.55	0.00
58	3.45	4.23	3.56	3.59	2.78	1.84	2.37	1.87	2.00	1.41	0.00
59	4.06	3.54	2.83	2.37	2.01	1.94	1.52	1.69	1.04	0.59	0.00
60	4.21	2.89	2.87	2.25	2.00	1.76	1.47	0.87	1.37	0.69	0.00
61	4.09	3.68	3.07	2.11	2.16	2.21	1.45	0.86	0.97	0.44	0.00
62	4.50	3.71	3.25	2.83	2.70	1.82	1.55	1.42	1.30	1.56	0.00
63	5.19	4.10	3.61	3.10	3.06	2.49	2.16	1.83	0.89	0.34	0.00
64	6.32	5.34	4.99	3.95	3.76	2.95	2.72	1.97	1.73	0.38	0.00
65	7.12	6.63	5.62	4.73	4.47	3.45	3.26	2.40	1.54	1.15	0.00
66	21.28	20.30	17.92	14.67	12.46	11.63	9.47	6.25	4.68	2.47	0.00
67	25.38	22.87	20.13	18.16	15.34	12.20	9.67	6.82	4.05	2.05	0.00
68	28.91	26.09	23.35	20.24	16.69	13.62	10.54	7.45	5.11	2.44	0.00
69	30.68	29.21	25.41	21.40	17.88	15.01	12.07	8.88	6.32	4.20	0.00
70	29.62	26.40	22.90	20.21	16.76	14.74	11.84	9.39	5.93	3.97	0.00
71	24.47	22.91	20.36	17.98	16.29	13.13	10.61	7.90	5.14	2.55	0.00
72	21.96	19.68	17.87	15.57	13.14	11.40	8.81	6.22	4.58	2.37	0.00
73	20.18	18.48	16.68	13.83	12.11	10.32	8.86	6.52	4.67	2.48	0.00
74	17.56	15.01	13.96	12.10	10.65	8.88	7.45	4.88	3.01	1.23	0.00
75	15.71	14.09	11.57	10.77	9.39	7.36	6.27	4.31	3.53	1.35	0.00
76	12.53	11.26	9.74	8.47	7.65	6.44	4.39	3.32	2.64	1.96	0.00
77	10.93	10.25	9.03	7.75	6.50	5.31	4.54	3.71	1.72	1.26	0.00
78	8.85	8.10	7.01	6.42	5.61	3.98	3.46	2.54	2.13	1.04	0.00
79	34.03	30.89	26.20	22.45	18.90	15.52	12.88	10.25	7.63	4.15	0.00
80	42.79	39.98	34.66	30.33	25.72	20.40	16.18	12.83	8.61	4.95	0.00

Color difference calculation for higher lightness range, and ID from 41 to 80

ID	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
41	3.49	7.63	10.05	12.13	13.83	15.10	15.76	16.85	16.53	15.88
42	3.20	6.09	9.20	10.81	12.68	13.90	15.09	15.71	16.08	16.05
43	2.66	5.94	8.10	10.15	12.41	13.60	15.00	15.42	15.67	15.82
44	2.92	4.29	6.46	9.37	10.95	11.56	12.22	13.36	13.71	13.68
45	1.79	3.47	5.90	7.15	8.99	10.69	11.70	12.43	13.47	13.56
46	1.54	3.29	5.20	7.27	9.00	10.69	12.06	12.98	14.27	15.31
47	2.28	3.52	5.26	6.83	8.56	10.27	11.17	12.25	13.88	14.40
48	2.43	3.11	4.70	6.66	7.37	9.04	10.08	11.31	12.10	13.07
49	1.76	2.18	3.83	5.57	6.08	7.50	8.70	9.84	10.11	11.33
50	1.08	2.44	2.94	3.85	4.92	5.49	6.69	7.74	8.82	9.50
51	0.54	0.80	1.81	3.35	3.54	4.75	5.63	7.05	7.49	8.23
52	1.31	1.57	2.22	2.81	3.54	4.60	5.42	6.27	7.32	8.39
53	1.80	3.03	2.90	2.80	2.87	0.62	2.73	0.96	1.35	1.50
54	0.96	2.97	2.70	1.56	2.40	0.69	1.66	1.03	1.74	1.52
55	1.91	1.96	2.90	4.06	1.93	1.90	2.62	2.73	1.79	1.70
56	1.74	3.51	2.74	3.69	2.87	1.82	2.05	2.27	2.74	1.88
57	0.14	2.03	2.19	1.96	1.45	1.66	1.87	1.94	2.26	2.22
58	1.87	2.50	3.51	2.50	2.80	2.50	2.59	3.75	4.28	4.22
59	1.32	2.12	2.65	3.39	3.25	2.31	3.10	2.96	3.13	3.35
60	0.53	0.89	1.22	1.79	1.70	2.81	2.67	2.95	3.11	3.35
61	0.33	1.21	2.14	1.51	2.34	1.91	3.59	3.34	3.54	3.31
62	0.55	0.83	1.05	1.93	1.80	2.84	2.89	3.45	3.39	4.18
63	1.44	1.91	2.22	2.50	3.09	3.37	3.55	4.50	4.69	5.24
64	0.99	0.82	1.36	2.27	2.77	3.15	3.76	4.29	4.75	5.48
65	0.52	1.47	1.50	2.21	2.66	2.72	4.02	5.23	5.80	6.55
66	1.66	2.76	4.07	6.10	7.43	9.45	10.74	12.62	14.46	15.73
67	2.45	3.23	5.29	8.27	9.77	12.14	14.07	17.63	19.50	21.78
68	1.61	4.26	6.31	9.79	13.41	15.49	18.37	21.45	24.72	27.34
69	2.87	4.70	8.42	11.83	14.58	18.09	21.41	25.15	27.93	31.34
70	3.08	5.23	7.88	11.30	14.95	17.84	21.04	24.64	27.05	29.73
71	2.18	4.40	6.97	10.16	12.55	15.87	18.14	20.86	23.11	25.07
72	2.37	4.00	6.00	8.32	10.52	12.94	14.61	17.04	18.20	20.39
73	2.21	2.93	5.07	7.59	9.16	11.07	13.11	14.52	16.07	17.94
74	2.39	3.36	4.55	7.22	8.57	10.19	11.48	13.00	14.14	15.56
75	1.86	2.55	3.71	5.62	6.91	7.65	9.10	10.58	11.52	12.74
76	1.59	2.33	3.62	4.51	5.69	6.39	7.71	8.75	10.08	11.11
77	1.39	1.34	2.72	3.45	4.52	5.11	6.31	7.07	8.83	9.84
78	1.34	1.69	2.32	3.33	3.49	4.28	5.56	7.14	7.23	8.32
79	2.62	3.99	6.65	9.22	11.86	13.98	16.79	17.78	19.46	20.18
80	2.08	3.62	7.71	13.14	16.43	20.02	22.96	24.63	26.84	28.40

Color difference calculation for lower lightness range, and ID from 81 to 120

ID	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
81	62.96	57.18	49.48	44.75	39.27	34.73	30.02	24.10	17.67	10.52	0.00
82	49.05	45.09	40.58	34.70	28.66	22.74	18.36	14.31	9.14	4.87	0.00
83	29.79	24.15	21.42	18.75	15.80	14.20	12.16	8.19	5.13	2.67	0.00
84	12.81	9.69	7.94	6.30	5.61	4.52	4.11	2.94	1.42	1.20	0.00
85	28.14	25.20	22.97	19.37	16.53	13.88	10.03	7.25	5.05	2.27	0.00
86	8.90	6.83	5.76	4.91	4.46	3.72	3.47	2.27	2.01	1.81	0.00
87	38.18	32.27	27.18	22.83	16.59	11.99	8.51	4.72	3.57	1.59	0.00
88	45.53	38.99	31.30	28.18	24.49	20.97	16.20	12.27	8.25	4.89	0.00
89	33.86	30.90	25.59	21.47	16.56	12.69	9.69	7.13	4.80	2.64	0.00
90	15.75	15.56	14.01	12.96	10.47	9.40	7.61	5.88	3.94	1.74	0.00
91	10.44	11.57	9.70	9.07	7.66	6.91	4.74	3.96	3.47	2.44	0.00
92	23.20	22.00	19.24	16.40	14.04	10.98	8.61	6.10	3.95	2.10	0.00
93	40.67	34.78	27.81	23.27	20.10	17.26	14.53	11.22	7.55	4.47	0.00
94	42.54	36.86	28.82	23.12	18.44	15.76	12.98	10.54	7.69	4.67	0.00
95	52.78	48.20	42.42	35.96	29.27	25.28	20.97	16.17	11.83	8.39	0.00
96	40.34	31.85	24.58	19.68	15.47	13.45	9.86	8.35	5.85	3.41	0.00
97	41.00	32.91	27.54	24.59	21.25	17.80	15.02	10.77	7.55	4.22	0.00
98	8.68	7.93	7.51	6.32	5.57	4.92	4.09	2.64	2.68	1.21	0.00
99	17.81	14.64	12.84	10.96	9.12	7.39	5.98	3.99	2.57	2.29	0.00
100	22.29	18.10	15.39	13.19	12.06	10.12	8.88	6.73	4.52	2.37	0.00
101	49.83	43.19	36.18	28.32	19.43	16.73	13.18	10.50	7.18	4.33	0.00
102	24.61	21.78	20.06	17.43	15.61	13.73	10.79	8.16	5.58	3.15	0.00
103	10.08	10.36	8.88	7.61	6.32	5.32	4.67	3.50	2.56	1.40	0.00
104	10.34	10.40	9.35	8.10	6.68	6.03	4.55	3.00	1.92	1.64	0.00
105	32.07	31.73	28.97	26.39	22.33	18.93	15.89	10.46	7.92	3.67	0.00
106	39.29	36.44	30.28	24.42	19.15	13.19	10.14	8.25	5.80	3.56	0.00
107	26.39	24.84	22.31	20.92	18.56	15.99	12.77	9.33	6.87	3.75	0.00
108	36.74	35.95	33.53	30.62	26.53	23.16	18.74	12.91	8.91	5.07	0.00
109	20.94	19.61	18.54	17.08	14.55	13.45	10.79	8.43	6.01	2.86	0.00
110	15.16	11.75	9.94	7.59	6.51	5.48	4.45	2.51	2.20	1.54	0.00
111	9.77	8.34	7.64	6.88	6.18	5.53	4.22	3.53	2.82	1.16	0.00
112	9.95	8.44	8.10	6.93	6.25	5.47	4.60	3.05	2.45	1.66	0.00
113	18.74	16.38	14.94	12.61	11.19	9.10	7.48	5.40	3.55	1.95	0.00
114	33.80	32.13	28.22	24.06	20.18	15.64	12.40	9.05	5.64	3.81	0.00
115	30.31	25.00	20.02	15.72	12.57	10.37	7.21	5.06	3.34	2.02	0.00
116	21.24	19.37	17.13	15.74	13.41	11.72	9.61	6.48	4.49	2.58	0.00
117	30.73	30.62	27.80	23.19	19.57	15.57	11.52	8.59	5.97	2.91	0.00
118	21.58	20.18	17.86	15.56	13.53	11.57	9.19	6.68	4.45	1.82	0.00
119	8.76	9.89	8.98	8.07	7.18	5.71	4.60	3.78	2.09	1.02	0.00
120	22.72	21.01	18.85	16.59	15.04	11.87	9.81	7.18	4.60	2.80	0.00

Color difference calculation for higher lightness range, and ID from 81 to 120

ID	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
81	3.68	8.21	11.49	12.26	12.48	13.28	13.41	14.34	14.74	14.56
82	1.94	4.83	8.47	11.98	14.45	16.79	19.22	22.72	25.07	26.71
83	2.67	5.29	7.53	10.83	12.08	12.69	13.87	14.74	15.98	16.12
84	1.94	2.92	4.00	5.48	6.41	6.69	7.98	9.70	11.18	13.12
85	1.95	2.56	4.14	6.93	9.14	11.84	14.59	17.56	20.05	21.88
86	2.08	3.25	3.38	4.45	4.83	4.11	4.86	6.89	7.32	6.92
87	2.29	4.17	6.63	8.68	11.21	13.02	16.08	17.11	18.94	20.33
88	4.26	5.97	9.79	14.82	18.57	22.47	24.96	27.13	27.45	26.18
89	2.62	4.12	7.99	11.44	14.10	17.22	19.93	22.86	24.61	26.59
90	2.92	3.00	5.37	7.39	8.42	10.91	12.26	13.62	14.90	15.74
91	0.93	1.00	0.85	2.53	1.70	2.77	2.28	4.56	5.26	5.22
92	1.00	1.11	2.47	3.73	5.76	7.37	8.07	9.66	10.64	12.08
93	4.55	8.00	11.76	15.68	19.14	22.83	24.62	25.59	25.75	26.41
94	3.87	7.82	11.97	15.90	19.30	22.36	24.91	26.35	26.77	27.60
95	2.98	7.53	14.34	18.66	23.12	25.65	27.14	27.37	27.46	27.02
96	3.03	6.90	9.77	13.25	16.34	19.60	21.70	23.42	23.95	24.99
97	3.71	6.26	10.25	14.14	17.91	19.44	21.16	23.16	23.72	24.23
98	1.59	1.53	2.66	4.40	3.93	4.86	6.02	7.01	7.92	8.32
99	3.08	3.85	5.31	8.24	9.98	10.93	13.51	15.73	17.74	18.36
100	3.21	5.38	7.73	10.79	13.34	15.53	17.63	19.78	21.10	22.44
101	4.00	7.25	10.64	13.93	16.68	19.22	21.88	24.97	26.91	28.24
102	3.25	5.41	7.69	10.90	13.50	16.35	17.82	20.18	21.87	23.31
103	1.03	0.51	1.97	3.24	3.67	4.93	5.59	8.14	8.48	8.95
104	1.47	2.40	2.91	5.23	5.35	7.65	7.94	10.45	11.57	12.67
105	0.91	2.03	3.45	4.99	7.20	9.38	10.28	13.04	14.52	17.45
106	3.81	7.28	11.78	16.06	19.88	23.40	26.80	30.18	32.92	35.52
107	3.01	5.31	8.57	11.85	14.86	17.69	19.89	22.49	23.85	25.81
108	1.54	2.20	3.48	5.85	6.70	8.11	9.19	11.30	13.08	14.56
109	2.81	4.37	7.08	9.76	12.16	14.97	16.74	19.32	21.64	22.98
110	1.81	1.14	1.15	2.37	2.58	3.15	4.15	5.38	6.19	6.18
111	1.85	3.52	3.99	5.21	5.99	7.05	8.25	10.30	11.27	12.34
112	1.84	1.86	2.54	4.09	4.21	5.45	6.14	7.43	8.32	8.75
113	2.31	3.48	5.23	7.76	9.54	11.12	12.73	14.71	16.05	17.65
114	2.56	2.07	3.05	5.02	6.19	7.15	9.32	11.37	13.07	14.40
115	2.47	4.07	6.35	9.82	12.55	15.09	18.10	21.01	22.78	25.08
116	2.14	4.11	6.07	8.28	11.00	13.12	14.42	16.40	17.27	19.11
117	2.07	1.77	3.36	6.21	7.99	10.22	11.99	15.57	17.64	20.33
118	2.26	3.64	5.84	8.45	10.65	13.54	15.07	17.31	18.70	19.88
119	1.00	0.81	1.59	3.54	3.63	4.51	5.28	6.99	7.37	7.91
120	2.38	3.84	6.68	9.17	12.20	14.16	16.42	18.56	20.33	22.34

Color difference calculation for lower lightness range, and ID from 121 to 160

ID	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
121	33.77	32.01	26.98	22.03	17.76	14.84	11.93	8.48	6.43	3.91	0.00
122	1.22	2.16	2.06	2.00	1.76	1.65	1.29	0.90	0.70	0.46	0.00
123	5.47	6.13	5.75	5.48	5.18	4.11	3.27	2.88	1.67	1.27	0.00
124	8.89	9.04	8.69	7.63	7.16	6.16	4.81	3.90	3.04	1.37	0.00
125	3.62	4.56	4.48	4.21	3.83	3.60	3.31	2.07	1.76	1.33	0.00
126	9.30	9.16	9.09	8.00	7.37	5.58	5.56	4.15	2.36	1.38	0.00
127	15.10	14.76	13.52	11.94	10.63	8.83	7.67	5.15	4.01	1.44	0.00
128	21.33	20.30	18.93	16.20	14.60	13.00	9.65	7.32	5.07	2.62	0.00
129	5.41	5.97	5.78	5.62	4.81	4.39	3.64	2.65	1.56	0.84	0.00
130	13.21	12.90	12.20	10.51	9.11	7.30	5.54	4.55	2.74	1.66	0.00
131	21.33	20.60	18.97	16.41	14.76	13.00	9.94	7.63	5.06	2.46	0.00
132	26.50	25.02	22.43	20.02	17.05	13.84	10.71	7.22	4.51	2.28	0.00
133	31.00	29.30	26.51	23.24	19.35	15.31	11.94	8.78	6.08	3.11	0.00
134	8.78	9.36	8.87	8.49	7.78	7.37	6.02	4.94	3.21	2.51	0.00
135	19.23	18.92	17.06	14.82	13.01	11.15	9.03	7.21	4.65	2.52	0.00
136	25.67	24.83	21.82	19.55	17.08	13.09	10.01	7.82	4.65	2.27	0.00
137	30.93	29.38	26.08	22.04	17.62	14.76	11.27	8.61	5.59	2.49	0.00
138	31.85	29.25	24.73	21.34	18.43	15.54	12.40	9.17	6.55	3.62	0.00
139	28.36	25.25	22.48	19.73	16.71	13.66	11.34	8.76	6.03	2.53	0.00
140	11.28	11.57	10.81	10.12	9.09	7.81	6.13	4.49	3.61	0.77	0.00
141	23.15	22.04	19.26	16.27	14.85	13.29	9.55	6.94	4.95	3.06	0.00
142	28.71	27.06	23.77	20.93	16.68	13.54	10.33	7.24	5.50	2.73	0.00
143	29.90	27.90	23.68	20.42	17.32	14.83	11.30	8.90	5.48	3.34	0.00
144	24.03	21.79	19.76	17.75	15.20	13.00	10.39	6.82	4.91	2.81	0.00
145	21.69	19.62	17.47	14.92	13.06	10.64	8.72	6.48	4.43	2.48	0.00
146	11.54	11.80	10.92	10.10	8.96	7.91	6.00	4.38	3.00	0.93	0.00
147	24.50	23.15	20.18	17.35	15.36	13.17	9.63	6.59	4.47	2.26	0.00
148	30.01	28.08	24.75	20.80	16.61	13.80	10.96	8.09	5.27	2.90	0.00
149	27.88	25.80	22.38	20.02	17.47	14.38	12.02	9.09	6.92	3.68	0.00
150	22.29	19.91	17.56	15.55	13.21	11.52	8.89	6.55	4.58	2.43	0.00
151	17.79	16.06	14.21	12.47	10.89	9.23	7.75	5.16	3.57	2.25	0.00
152	22.92	22.63	20.94	19.02	17.49	14.53	11.60	7.99	5.22	2.90	0.00
153	28.29	26.75	24.21	21.57	18.20	14.39	10.57	7.22	4.66	2.09	0.00
154	32.84	30.57	26.88	22.00	18.49	15.40	11.81	8.67	5.69	3.51	0.00
155	25.48	23.36	20.62	18.22	15.85	13.36	11.26	7.56	5.15	2.96	0.00
156	18.05	16.21	14.40	12.65	11.32	9.65	7.61	5.76	3.51	2.25	0.00
157	14.36	12.44	10.86	9.30	8.24	7.11	5.58	3.62	2.94	2.33	0.00
158	10.90	9.70	8.06	6.73	6.28	4.97	4.30	2.50	1.58	1.00	0.00
159	26.27	24.04	21.89	19.82	17.36	15.19	12.50	9.05	6.22	3.93	0.00
160	46.36	42.19	37.45	31.09	26.56	23.44	18.83	14.78	10.96	6.65	0.00

Color difference calculation for higher lightness range, and ID from 121 to 160

ID	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
121	3.18	4.86	8.36	12.06	15.02	18.38	21.77	24.66	27.38	30.19
122	0.52	0.54	1.12	1.80	1.98	2.60	3.30	3.92	4.43	5.03
123	0.67	1.05	1.01	2.30	2.83	3.81	5.37	5.93	6.96	7.34
124	0.80	1.15	1.62	3.71	5.57	7.17	9.12	10.91	12.55	13.61
125	0.24	0.20	0.73	1.36	1.97	3.35	4.10	4.90	5.52	6.03
126	1.38	1.31	2.49	4.25	5.37	6.48	8.32	10.68	11.88	12.73
127	2.56	2.59	5.29	7.43	8.75	11.07	12.38	14.20	15.42	16.57
128	2.65	2.93	5.16	7.18	8.89	10.50	11.71	14.24	15.68	17.46
129	0.90	1.17	1.79	2.49	4.04	5.06	5.23	7.04	7.98	8.02
130	2.51	2.69	4.97	8.14	8.27	10.18	10.55	13.19	14.18	15.51
131	2.06	2.84	5.03	7.72	8.77	11.28	12.63	14.70	16.17	17.60
132	2.95	4.26	6.54	9.34	10.70	13.32	15.73	19.04	20.98	23.51
133	1.91	4.56	6.64	10.00	13.37	15.92	18.76	22.27	24.83	28.21
134	1.05	0.72	2.12	3.56	4.06	5.02	6.45	8.22	8.61	10.33
135	2.09	2.83	4.25	6.52	7.64	9.44	11.14	13.32	14.96	15.70
136	2.07	3.87	5.12	8.22	9.84	12.58	14.95	17.68	20.15	21.96
137	2.41	4.38	7.20	10.87	13.50	16.89	19.70	23.10	25.83	28.79
138	3.07	5.14	8.30	11.53	14.65	18.82	21.57	25.14	28.21	30.81
139	3.37	5.33	8.04	11.38	14.40	17.98	20.87	23.89	26.60	28.73
140	0.93	1.17	2.31	4.15	5.51	7.39	8.13	10.27	11.41	12.36
141	2.63	2.97	4.58	6.45	8.58	10.15	11.93	14.55	16.16	18.33
142	2.77	4.23	6.72	10.27	13.63	16.08	18.05	22.05	24.72	27.52
143	3.67	5.56	8.33	12.38	14.89	18.35	20.96	24.82	27.86	30.44
144	2.16	4.04	6.81	9.74	12.05	14.87	17.18	19.60	21.27	23.25
145	2.49	3.98	6.20	8.42	10.54	12.58	14.44	16.48	18.61	20.05
146	1.33	2.34	3.39	5.14	7.65	7.90	9.71	11.49	13.14	13.90
147	2.00	2.06	4.58	7.20	8.92	10.93	13.29	15.38	17.62	20.40
148	2.72	4.70	7.87	11.36	13.95	16.86	19.88	23.79	26.81	29.47
149	2.26	4.55	7.18	11.05	13.84	16.76	19.63	23.00	25.33	27.56
150	1.72	3.69	5.64	8.45	10.46	12.74	14.65	16.36	17.81	19.67
151	1.98	2.65	4.76	6.86	7.58	9.63	10.93	12.92	13.60	15.65
152	2.95	3.20	4.68	7.10	8.34	10.32	11.59	13.87	15.81	16.96
153	2.34	3.20	5.61	8.27	10.90	14.12	16.06	19.41	21.84	24.30
154	3.12	5.29	8.59	12.19	15.18	18.53	21.82	25.70	28.24	31.49
155	2.54	4.47	7.09	10.61	13.46	16.16	18.55	21.83	23.39	25.47
156	2.07	3.12	4.70	7.22	8.64	10.21	11.38	13.72	14.66	16.34
157	1.28	2.17	3.63	4.52	5.23	6.59	7.86	8.89	10.55	11.42
158	0.81	1.52	2.26	3.30	4.16	5.19	5.99	7.10	8.27	9.27
159	2.88	4.23	7.11	10.38	12.25	14.19	16.54	18.41	20.24	21.13
160	4.26	8.62	13.82	17.93	21.49	24.94	27.57	28.89	29.35	29.58

Color difference calculation for lower lightness range, and ID from 161 to 182

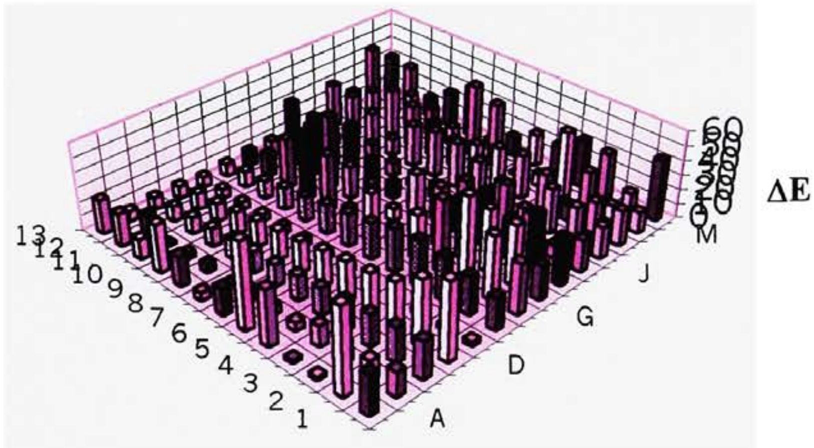
ID	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
161	8.54	5.75	4.08	3.82	2.99	2.73	2.50	1.96	0.78	0.78	0.00
162	1.27	3.32	2.14	2.48	1.38	1.17	1.30	1.02	0.72	0.52	0.00
163	43.38	37.25	29.93	24.30	20.72	16.61	14.06	10.38	7.13	3.77	0.00
164	49.76	43.36	39.34	33.02	27.71	24.24	19.83	15.36	11.24	5.48	0.00
165	12.70	12.27	10.79	9.61	8.60	7.04	6.04	4.26	3.89	2.23	0.00
166	19.23	17.23	15.34	14.16	12.59	10.66	8.72	6.67	4.65	2.68	0.00
167	22.56	19.35	18.60	16.35	15.36	13.86	11.30	8.78	6.16	3.34	0.00
168	2.72	4.69	4.23	4.11	3.08	2.94	2.46	1.75	1.23	1.00	0.00
169	43.24	37.29	32.76	27.27	22.14	17.25	13.09	8.53	6.40	3.22	0.00
170	42.02	38.54	34.21	29.65	25.49	21.42	15.69	10.57	8.25	4.98	0.00
171	11.20	10.92	9.75	8.42	7.42	5.91	5.25	3.49	2.27	1.39	0.00
172	31.19	26.09	20.94	16.72	13.21	10.21	7.90	5.62	3.65	1.84	0.00
173	32.30	27.02	22.25	17.45	12.38	10.28	8.47	6.58	4.78	3.04	0.00
174	21.19	20.88	18.58	16.67	13.27	10.83	8.87	6.33	3.74	2.26	0.00
175	22.18	22.09	20.54	18.52	16.39	13.88	11.66	9.50	6.32	4.07	0.00
176	13.22	10.18	8.76	7.83	7.24	6.40	5.39	3.64	1.92	0.69	0.00
177	3.37	5.22	4.62	3.95	3.91	3.48	3.09	2.30	1.78	1.33	0.00
178	34.54	32.88	29.92	27.39	23.89	19.35	16.45	13.03	9.12	5.63	0.00
179	24.02	23.21	21.71	20.09	17.13	15.10	12.84	9.90	6.52	3.11	0.00
180	13.54	14.19	13.40	11.44	9.45	8.23	6.13	4.69	3.48	1.83	0.00
181	30.04	28.35	25.95	22.02	18.13	13.20	9.86	6.78	3.97	2.40	0.00
182	31.41	28.11	25.28	21.88	17.93	15.28	11.95	7.87	5.12	2.57	0.00

Color difference calculation for higher lightness range, and ID from 161 to 182

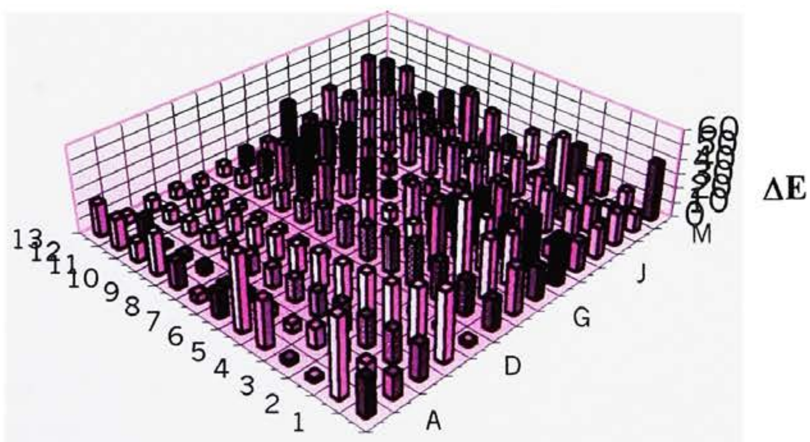
ID	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
161	1.25	1.98	2.11	3.59	3.53	4.62	4.97	5.54	6.47	6.37
162	0.44	1.05	1.22	0.76	0.34	0.54	0.23	0.96	1.06	1.16
163	2.73	3.60	6.33	9.34	10.78	12.52	14.63	16.42	17.66	19.69
164	2.78	6.59	12.17	17.52	20.97	23.66	27.68	30.01	31.22	31.43
165	2.43	2.51	3.56	6.11	6.81	8.46	9.73	11.91	12.76	13.92
166	2.26	3.70	6.24	8.66	10.70	12.97	13.73	15.72	16.72	18.48
167	2.77	4.93	8.39	11.43	14.03	16.74	19.21	21.59	23.76	25.25
168	0.35	0.85	0.74	0.61	0.96	0.49	0.35	1.17	1.15	1.21
169	1.83	2.55	5.28	7.35	10.27	12.76	14.52	16.98	19.90	20.38
170	2.09	6.35	9.57	13.24	16.03	19.08	22.49	27.28	31.33	34.38
171	1.33	1.40	2.74	4.33	5.37	7.14	8.55	10.35	10.98	12.53
172	3.09	5.00	7.68	11.43	14.25	17.05	19.86	22.49	24.38	26.13
173	1.70	5.19	8.53	12.13	15.24	18.64	21.68	24.90	27.16	30.14
174	1.47	1.66	3.31	5.04	6.35	7.64	9.64	11.31	12.68	13.87
175	2.10	5.99	8.34	12.34	12.60	14.49	16.02	18.65	20.44	22.32
176	0.00	1.11	1.74	3.10	4.16	4.76	5.62	6.67	7.56	7.94
177	0.52	1.16	1.19	1.87	2.11	2.99	3.27	4.82	5.23	5.74
178	2.62	4.44	6.83	8.67	11.35	12.31	13.68	15.32	16.43	18.47
179	3.37	5.55	9.65	13.48	14.91	16.60	18.48	20.15	22.81	24.90
180	0.50	0.57	2.21	3.26	4.27	5.13	5.69	7.78	8.78	10.11
181	2.93	3.72	4.79	6.79	8.54	9.85	11.49	14.30	16.45	18.85
182	2.30	2.27	3.36	5.88	6.64	7.36	7.96	11.29	13.30	14.56

In the following three-dimensional graphs, only the dark area (lower values of the lightness range) is shown. The sample that matched with the reference is included.

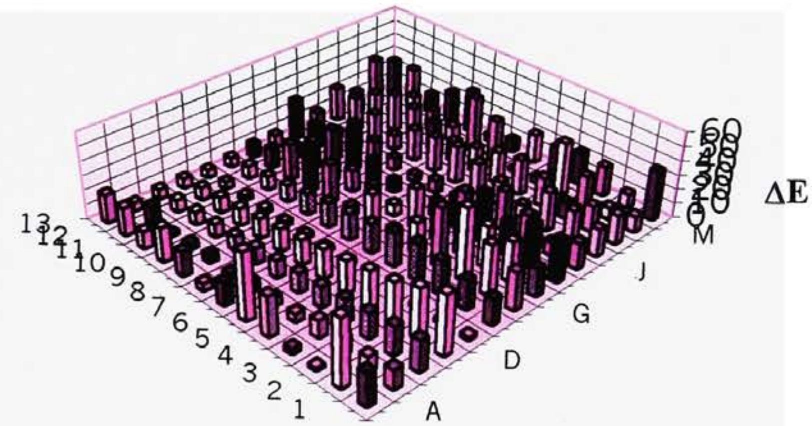
ΔE^*_{ab} Plot for Sample with lightness equal to –50 units.



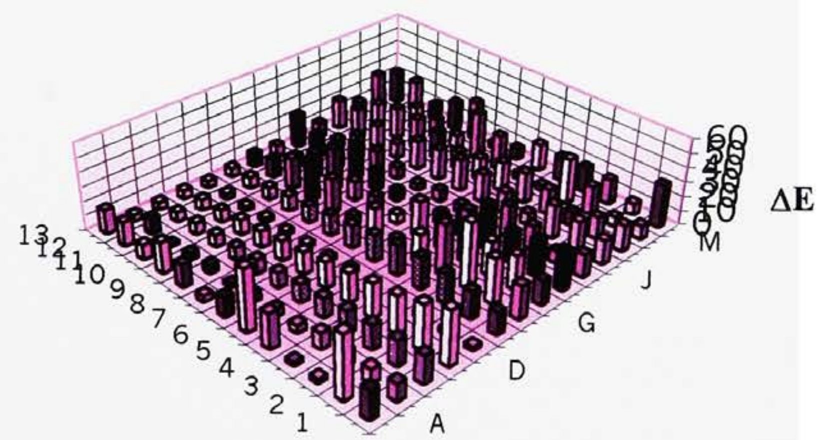
ΔE^*_{ab} Plot for Sample with lightness equal to –45 units.



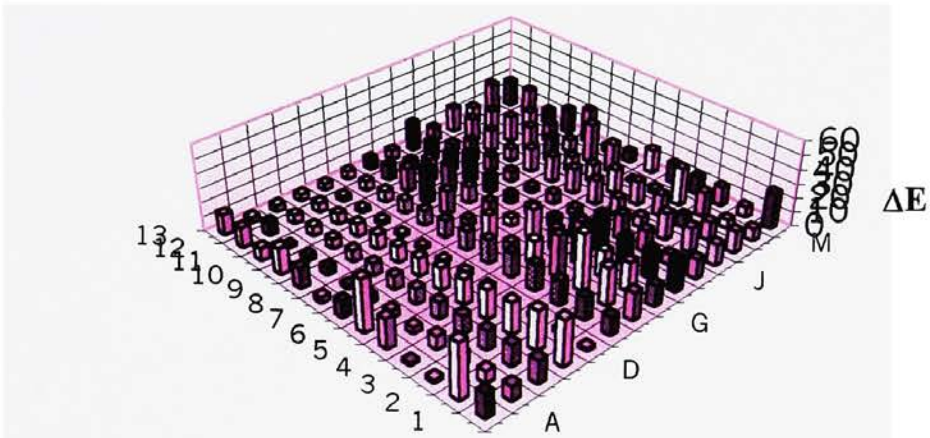
ΔE^*_{ab} Plot for Sample with lightness equal to –40 units.



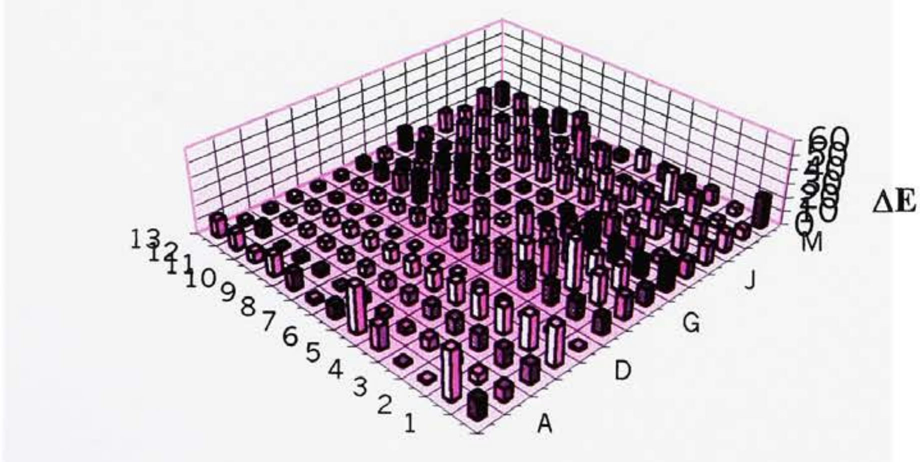
ΔE^*_{ab} Plot for Sample with lightness equal to –35 units.



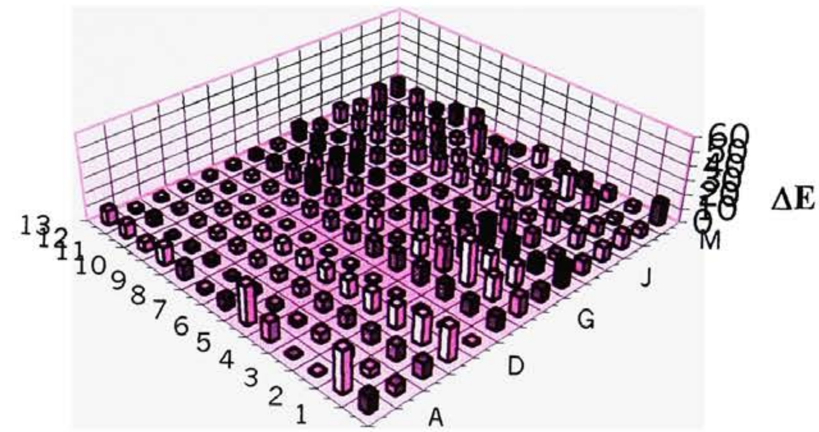
ΔE^*_{ab} Plot for Sample with lightness equal to –30 units.



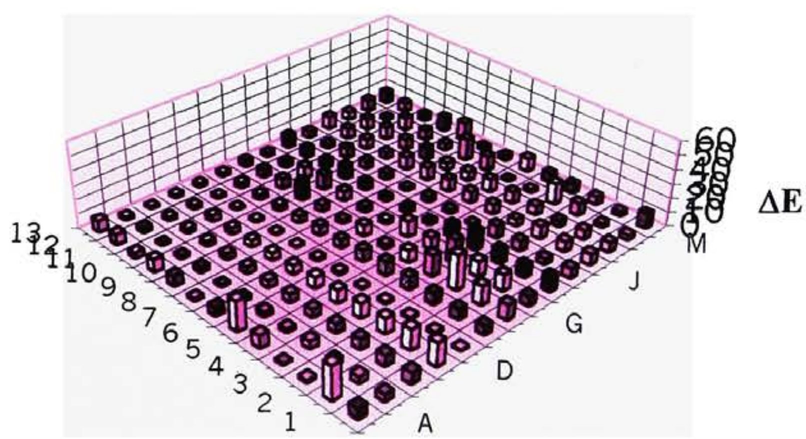
ΔE^*_{ab} Plot for Sample with lightness equal to –25 units.



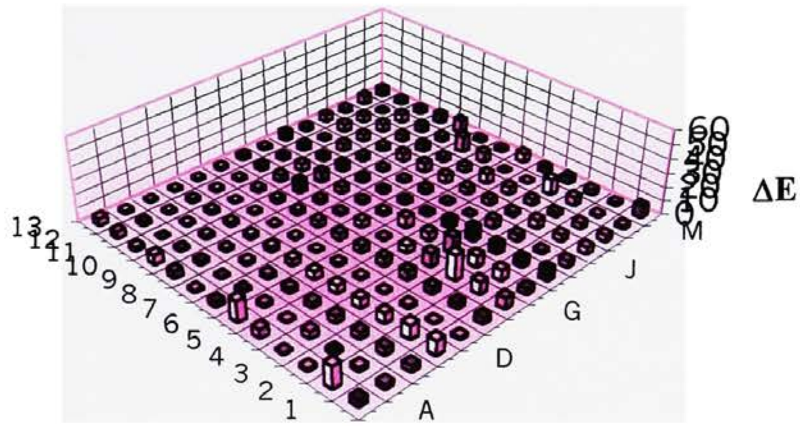
ΔE^*_{ab} Plot for Sample with lightness equal to –20 units.



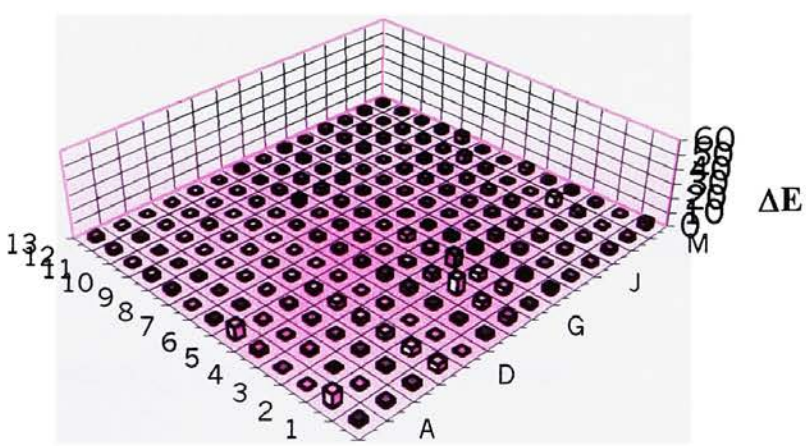
ΔE^*_{ab} Plot for Sample with lightness equal to –15 units.



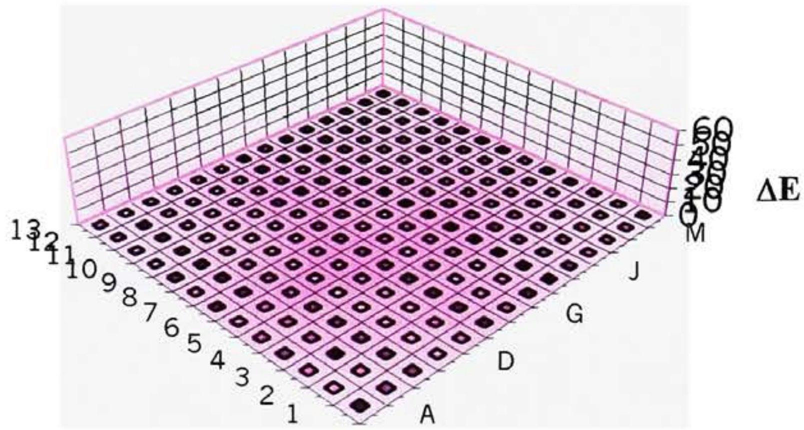
ΔE^*_{ab} Plot for Sample with lightness equal to –10 units.



ΔE^*_{ab} Plot for Sample with lightness equal to –5 units.



ΔE^*_{ab} Plot for Sample with lightness equal to 0 units (sample that match with the reference).



Then, the averaged ΔE^*_{ab} values, are:

	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
Average DE	20.85	19.12	16.85	14.67	12.50	10.47	8.46	6.23	4.35	2.42	0.00
Standard Dev.	13.29	11.75	10.22	8.84	7.45	6.32	5.16	3.95	2.74	1.61	0.00

	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
Average DE	1.99	3.27	5.02	7.14	8.63	10.23	11.70	13.47	14.69	15.81
Standard Dev.	0.96	1.88	2.95	3.92	4.87	5.73	6.42	7.11	7.64	8.22

From this table, the ΔE^*_{ab} (metric) scale was obtained.

From the improved color difference equation shown in Chapter 2 as:

Using the Hue difference as:

$$\Delta H^{*}_{94} = \sqrt{(\Delta a*)^2 + (\Delta b*)^2 - (\Delta C*)^2}$$

the improved color difference equation is [8]:

$$\Delta E^{*}_{94} = \sqrt{\left(\frac{\Delta L^{*}}{k_L S_L}\right)^2 + \left(\frac{\Delta C^{*}_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^{*}_{ab}}{k_H S_H}\right)^2}$$

where the weighting functions:

$S_L = 1$

$S_C = 1 + 0.045\ C^{*}_{ab}$

$S_H = 1 + 0.015\ C^{*}_{ab}$

and, the parametric factors:

$k_L = 1$

$k_C = 1$

$k_H = 1$

The ΔE^*_{94} color difference values for this improved equation are:

Step	ΔE^*_{94} Scale
5	14.82
4	10.75
3	6.36
2	2.74
1	0.00
2	-7.09
3	-10.53
4	-14.27
5	-17.84

From this table, the ΔE^*_{94} scale was obtained.

Finally, from the data shown in the Table No. 4: Observer's judgments for the Visual scale, in Chapter 6: The Results, and identifying the sample number from the table for ΔE^*_{ab} to each step, the Visual scale was built as follows:

Step	Visual Scale	$\overline{\Delta E^*_{ab}}$ Scale	ΔE^*_{94} Scale
5	15.81	15.81	14.82
4	12.17	12.59	10.75
3	7.20	8.63	6.36
2	3.39	4.15	2.74
1	0.00	0.00	0.00
2	-8.88	-5.29	-7.09
3	-12.63	-10.47	-10.53
4	-16.39	-15.76	-14.27
5	-20.85	-20.85	-17.84

Appendix J. Hypothesis testing procedure applied.

Applying the classical seven-step hypothesis testing procedure shown in Step 6: Psychometric-Colorimetric Correlation, Chapter 5: Methodology, to the Visual and $\overline{\Delta E^*_{ab}}$ scales shown in Appendix I for higher lightness range, the results were:

Step 1: State the null and alternative hypotheses. The assumption to be tested and the conclusion that it was accepted contingent.

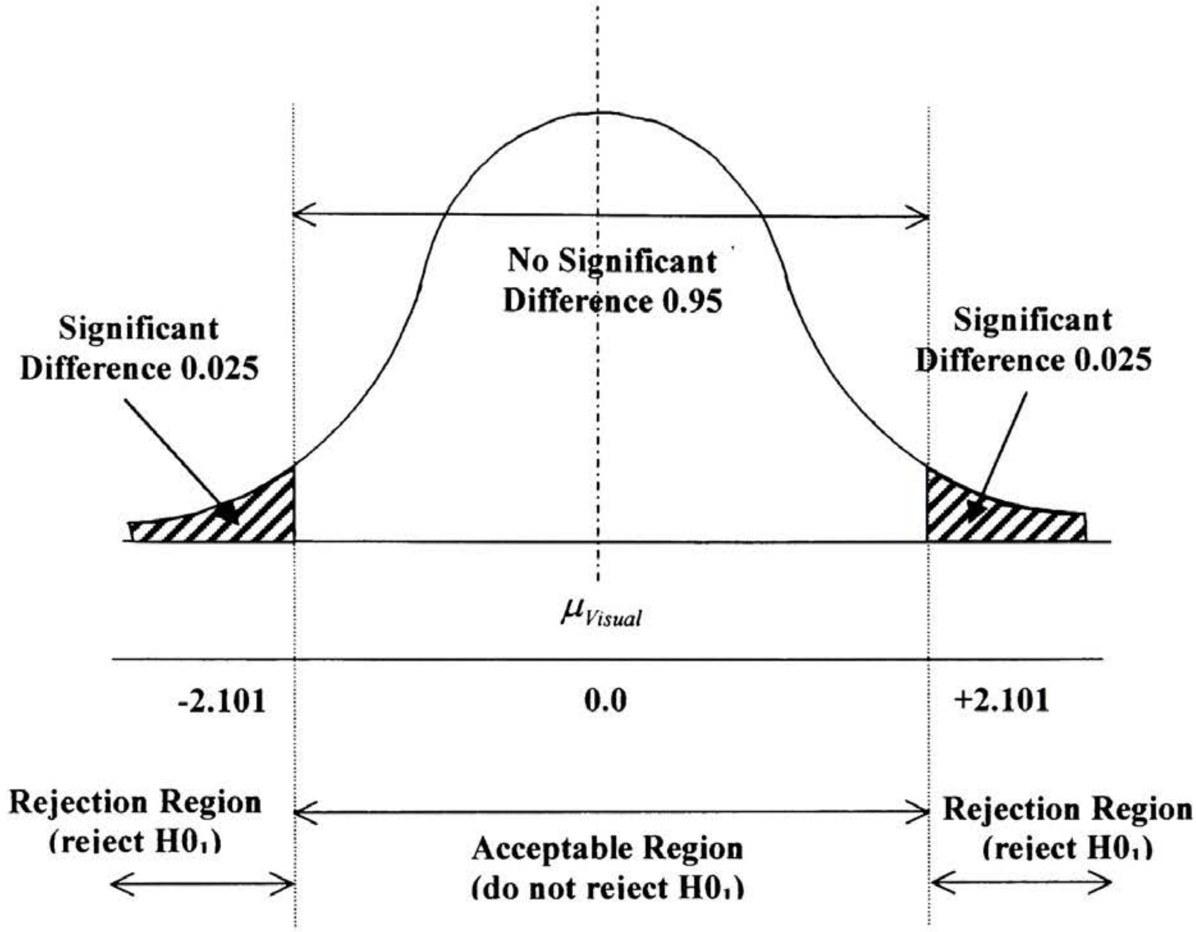
Null hypothesis, $H0_2$: there is a relationship between the Visual scale and the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 50 and 100 units. The hypothesized value of the population mean for the Visual scale (μ_{Visual}) must be equal to the population mean for the Metric scale ($\mu_{\Delta E^*_{ab}}$) in each step scale.

Alternative hypothesis, $H1_2$: there is no relationship between the Visual scale and the colorimetric scale when using the average of CIELAB ΔE^*_{ab} color difference in ICC-based CMS for lightness values in between 50 and 100 units. The hypothesized value of the population mean for the Visual scale (μ_{Visual}) must not be equal to the population mean for the Metric scale ($\mu_{\Delta E^*_{ab}}$) in each step scale.

Step 2: Select the level of significance. The minimum acceptable probability of occurrence for a difference between parameters. In each step of the scales a level of significance (α) of 0.025 is stated (a 95% of confidence interval).

Step 3: Determine the test distribution to use. In each step of the scales a "t" distribution is used, because the sample size (n) is less or equal to 30 and the standard deviation (σ) is unknown.

Step 4: Define the rejection or critical regions. Part of the sampling distribution that is specified as being unlikely. With a level of significance of 0.025 in each tail, the remaining area in each half of the sampling distribution is 0.475 (0.500 – 0.025) and shown in the next graph.



Step 5: State the decision rule. Formal statement of the appropriate conclusion to be reached. Reject $H0_2$ if the standardized difference between parameters falls into a rejection region. Otherwise, fail to reject $H0_2$ (accept $H1_2$).

For higher lightness range:

Reject $H0_2$ for step of the scale No. 5 if

$\mu_{\Delta E^*_{ab}} < 15.81$

Or $\mu_{\Delta E^*_{ab}} > 15.81$

Reject $H0_2$ for step of the scale No. 4 if

$$\mu_{\Delta E^*_{ab}} < 12.17 - (2.101)(0.18) = 11.78$$

Or $\mu_{\Delta E^*_{ab}} > 12.17 + (2.101)(0.18) = 12.55$

Reject $H0_2$ for step of the scale No. 3 if

$$\mu_{\Delta E^*_{ab}} < 7.20 - (2.101)(0.27) = 6.63$$

Or $\mu_{\Delta E^*_{ab}} > 7.20 + (2.101)(0.27) = 7.76$

Reject $H0_2$ for step of the scale No. 2 if

$$\mu_{\Delta E^*_{ab}} < 3.39 - (2.101)(0.28) = 2.79$$

Or $\mu_{\Delta E^*_{ab}} > 3.39 + (2.101)(0.28) = 3.98$

For lower lightness range:

Reject $H0_1$ for step of the scale No. 2 if

$$\mu_{\Delta E^*_{ab}} < 7.88 - (2.101)(0.52) = 6.80$$

Or $\mu_{\Delta E^*_{ab}} > 7.88 + (2.101)(0.52) = 8.97$

Reject $H0_1$ for step of the scale No. 3 if

$$\mu_{\Delta E^*_{ab}} < 12.31 - (2.101)(0.35) = 11.57$$

Or $\mu_{\Delta E^*_{ab}} < 12.31 - (2.101)(0.35) = 13.05$

Reject $H0_1$ for step of the scale No. 4 if

$$\mu_{\Delta E^*_{ab}} < 16.62 - (2.101)(0.16) = 16.29$$

Or $\mu_{\Delta E^*_{ab}} < 16.62 - (2.101)(0.16) = 16.95$

Reject $H0_1$ for step of the scale No. 5 if

$$\mu_{\Delta E^*_{ab}} < 20.85$$

Or $\mu_{\Delta E^*_{ab}} < 20.85$

Step 6: Make the necessary computations. Conversion of the difference between parameters into a standardized value.

	Step	Min	Delta E	Max
Higher lightness Range	5	15.81	15.81	15.81
	4	11.78	12.59	12.55
	3	6.63	8.63	7.76
	2	2.79	4.15	3.98
	1	0.00	0.00	0.00
Lower lightness Range	2	6.80	5.29	8.97
	3	11.57	10.47	13.05
	4	16.29	15.76	16.95
	5	20.85	20.85	20.85

Step 7: Make a statistical decision. If the standardized value falls into a rejection region, the Null hypothesis is rejected. Otherwise, accept.

	Step	Min	Delta E	Max	Statistical Decision
Higher lightness Range	5	15.81	15.81	15.81	Accepted
	4	11.78	12.59	12.55	Rejected
	3	6.63	8.63	7.76	Rejected
	2	2.79	4.15	3.98	Rejected
	1	0.00	0.00	0.00	Accepted
Lower lightness Range	2	6.80	5.29	8.97	Rejected
	3	11.57	10.47	13.05	Rejected
	4	16.29	15.76	16.95	Rejected
	5	20.85	20.85	20.85	Accepted

Appendix K. Example of ΔE^{*}_{ab} Distribution procedure.

In addition to the procedure shown in Figure No. 14, Chapter 5: Methodology, an example of ΔE^{*}_{ab} distribution procedure is represented here. The information is referring to real data measured.

ΔE^{*}_{ab} Distribution table

ΔE	Frequency	Cumulative %
0	1	.55%
4	86	47.80%
8	64	82.97%
12	21	94.51%
16	9	99.45%
20	1	100.00%
24	0	100.00%
28	0	100.00%
32	0	100.00%
36	0	100.00%
More	0	100.00%

CRF distribution plot